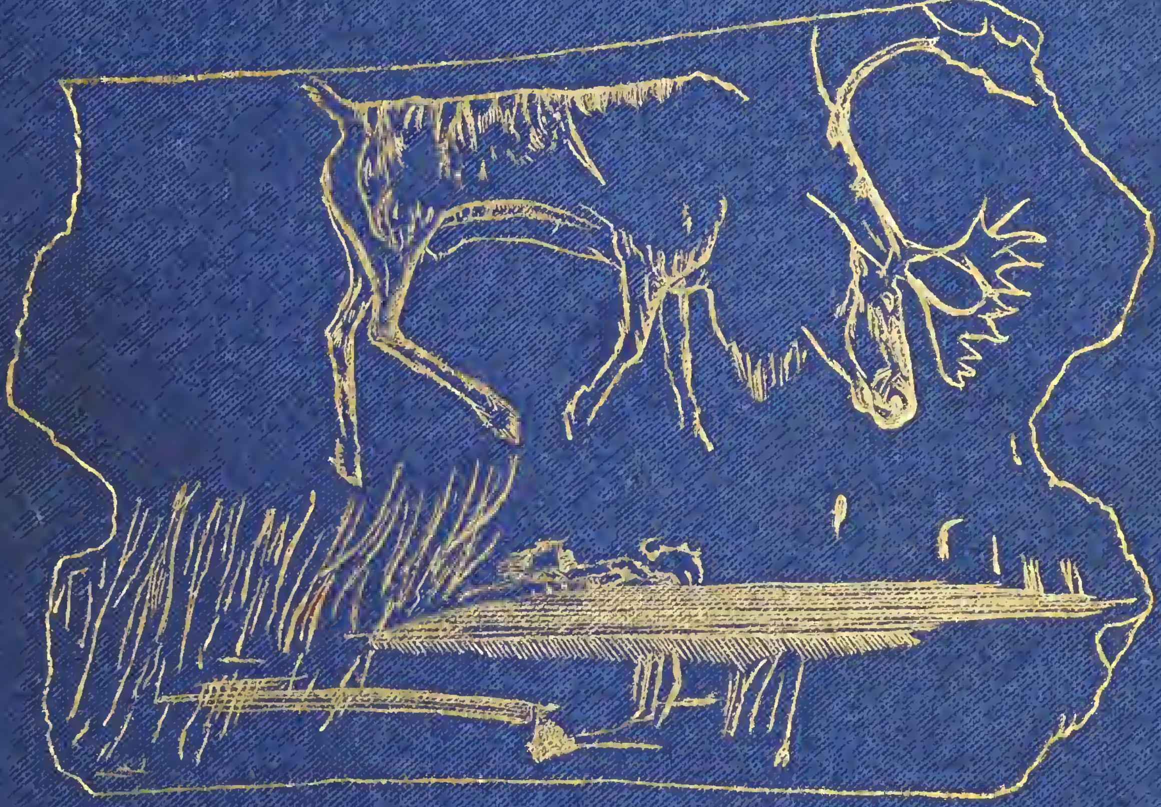

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PREHISTORIC EUROPE

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THE GREAT ICE AGE,

AND ITS RELATION TO THE ANTIQUITY OF MAN.

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PREHISTORIC EUROPE

A GEOLOGICAL SKETCH

By JAMES GEIKIE, LL.D., F.R.S.
OF H.M. GEOLOGICAL SURVEY OF SCOTLAND
AUTHOR OF THE 'GREAT ICE AGE'

MAPS AND ILLUSTRATIONS

LONDON
EDWARD STANFORD, 55 CHARING CROSS, S.W.
1881

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PREFACE.

THE object of these pages is to give an outline of what appear to have been the most considerable physical changes experienced in our continent since the beginning of the Pleistocene or Quaternary Period. Several general works, by some of our most accomplished geologists and archæologists, have already dealt with the subject in part, and it is impossible, therefore, that a new essay in Post-tertiary geology can avoid discussing certain evidence which is perhaps sufficiently familiar even to non-specialists. But none of the treatises referred to quite covers the ground I have endeavoured to occupy. While some of my predecessors have examined the evidence principally from the point of view of the archæologist, and others from that of the palæontologist, my aim has been to describe in a more systematic manner than has hitherto been attempted that succession of changes, climatic and geographical, which, taken together, constitute the Historical Geology of Pleistocene, Postglacial, and Recent times.

In a former work (*The Great Ice Age*) I have already discussed some of the questions which form the subject-matter of the present volume, and to a certain extent, therefore, the latter may be considered as supplementary to its predecessor. The two works, however, are quite independent. The *Great Ice*

Age is for the most part occupied with a somewhat detailed description of the Glacial deposits, and an exposition of the principles upon which these are interpreted. It gives only a meagre account of the cave- and river-accumulations which have yielded traces of man and the Pleistocene mammals, while the more recent deposits, with the exception of those of Scotland, are passed over with merely a few general remarks. This mode of treatment was necessitated by the object I had in view, which was to point out to English geologists that in their endeavours to arrange chronologically the ossiferous and Palæolithic accumulations sufficient attention had not been paid to the results which had accrued from a study of Glacial and Interglacial formations. And I sought by a rigid analysis of the evidence to show that the Palæolithic deposits, which had hitherto been classed by them as of Postglacial age, could not possibly belong to so late a period, but ought to be referred to Interglacial, and probably in part also to Preglacial, times. The plan of my former work, however, did not allow of so full a treatment of this part of the subject as its importance demanded, and the preparation of the present book was forthwith commenced, with the view of supplying such deficiency, and of still further illustrating and substantiating my general argument.

Many questions, which hardly came within the scope of my previous essay, are here discussed at some length. Chief among these are the physical changes that characterised the Postglacial and Recent Period. Since the appearance of Edward Forbes's well-known paper on the Geological Relations of the Fauna and Flora of the British Islands, great advances have been made in our knowledge of the later chapters of the geological record; and I have taken advantage of this fuller information to reconsider some of those questions of geographical and climatic change which the genius of Forbes suggested. The subject is extremely fascinating, and deserving of more attention than it has of late years received. But Mr. Wallace's important and interesting work (*Island Life*), which has just appeared while I pen these lines, will doubtless give a fresh impulse to the study among naturalists, and should the present volume assist in the same direction, I shall feel well repaid for my labour.

The reader will not, I hope, have any difficulty in understanding the precise signification I attach to such terms as "Prehistoric," "Pleistocene," "Preglacial," "Glacial," "Interglacial," "Postglacial," etc. But it may be as well to state here that I employ the term "Prehistoric" in the same extended sense as Professor D. Wilson, by whom "it was purposely coined to express the whole period disclosed to us by means of archæological evidence, as distinguished from what is known through written records." In the classification adopted by me, "Pleistocene" or "Quaternary" includes the Preglacial, Glacial, and Interglacial deposits; while "Postglacial" is restricted to those accumulations which belong to a later date than the last great extension of glacier-ice in Europe—a sense in which it has long been employed in Scotland, Scandinavia, Switzerland, and the Continent generally. This differs somewhat from the classification advanced by certain English geologists, who would include under the term "Postglacial" many accumulations of Pleistocene age, which it is the object of these pages to show are of Interglacial, and not Postglacial, date.

To the many friends and correspondents at home and abroad, who have kindly satisfied my inquiries and favoured me with copies of their papers, I would here express my grateful thanks. I have also to acknowledge my indebtedness to Dr. J. Evans, who has courteously allowed me to copy from his great work on Ancient Stone Implements the illustrations which are given in Plate C. And to Professor T. Rupert Jones similar acknowledgments are due for permission to reproduce those illustrations of Palæolithic Implements which are taken from *Reliquiæ Aquitanicæ*, and which appear in Plate B. I have further to thank my friend Dr. Buchanan White for many important suggestions and much assistance while my work was in preparation. I have enjoyed the great advantage of discussing with him many of the questions which form the chief subject-matter of this volume, and his wide and accurate knowledge of the geographical distribution of plants and animals, which he generously placed at my disposal, has been of most essential service.

PERTH, *October* 1880.

CONTENTS.

CHAPTER I.

INTRODUCTORY . . . . . Pages 1-4

CHAPTER II.

ARCHÆOLOGICAL PERIODS.

Classification of Human Relics—Stone Age, Bronze Age, and Iron Age—Phases of Civilisation—Gradual transition from Stone Age into Bronze Age, and Bronze Age into Iron Age—Palæolithic and Neolithic Periods—Palæolithic Implements—Classification of Palæolithic Cave-relics—Conditions of life in Palæolithic Period—Human Remains—Break in Succession between Palæolithic and Neolithic Periods. 5-24

CHAPTER III.

CLIMATE OF PLEISTOCENE PERIOD—TESTIMONY OF MAMMALIA.

Geographical distribution of Mammals—Southern, Northern, and Temperate Group—Evidence of Mammalia as to Climate—Present climatic conditions in Europe, Northern Asia, and boreal regions of North America—Region of Tundras and Barrens—Arctic Forest Zone—Annual Migrations in Siberia—Similar migrations cannot take place in Europe—Influence of the Gulf Stream on European Climate—Probable effect of its withdrawal—Alternations of Climate during Palæolithic Period 25-43

CHAPTER IV.

CLIMATE OF PLEISTOCENE PERIOD, *continued*—TESTIMONY OF PLANTS AND MOLLUSCS.

Preservation of land-plants exceptional—Plants in the Travertine of Massa Marittima in Tuscany—Plants in tufas of Provence; in tufas of Montpellier, etc.; in tufa of La Celle near Paris—Views of Count Saporta—Plants in tufa of Canstadt—Pleistocene lignite of Jarville near Nancy; its plant and insect remains—Mr. Nathorst on Arctic flora in peat of Switzerland, Germany, etc.; M. Tournouër on shells in tufa of La Celle—M. Bourguignat on shells in "diluvium gris" of Paris—Shells in tufas of Canstadt; in English Pleistocene deposits—Dr. Sandberger on shells and mammalian remains in löss of Würzburg—M. Locard on shells in Corsican breccias—Summary of evidence . . . . . Pages 44-68

CHAPTER V.

CAVE-DEPOSITS OF THE PLEISTOCENE PERIOD.

Caves of different kinds—Mode of their formation—Absence of Pliocene organic remains in European caves—General character of cave-accumulations—Commingling of human relics with remains of extinct mammalia—"Break" between Palæolithic and Neolithic times—Stalagmite; its formation and rate of growth—Mr. Pengelly's observations on stalagmitic accretion in Kent's Cavern—Stalagmitic growth not continuous—Calcified earth, sand, and gravel in caves—Angular blocks, *débris*, and breccia in caves—Succession of deposits in Brixham Cave—Professor Prestwich on the geological history of that cave—Contemporaneity of man and the old mammalia—Extreme antiquity of Pleistocene Period . . . 69-89

CHAPTER VI.

CAVE-DEPOSITS OF THE PLEISTOCENE PERIOD—*Continued.*

Succession of deposits in Kent's Cavern—Conditions during their accumulation—Evidence for prolonged duration of Palæolithic Period—Hyæna dens in England—Kirkdale Cave and Wookey Hole—Bone-caves never tenanted by man or wild beasts—Victoria Cave, near Settle in Yorkshire—Succession of deposits in that cave—Glacial bed associated with Pleistocene deposits—Bone-caves of Belgium—General succession of deposits in these—Trou du Sureau—Relative position of Neolithic relics . . . Pages 90-104

CHAPTER VII.

CAVE-DEPOSITS OF THE PLEISTOCENE PERIOD—*Continued.*

Bone-caves of Belgium—The Trou Magrite—Contrast between lower and upper deposits—Trou de la Naulette—Human bones associated with remains of extinct animals—The Cavern of Goyet—The Trou du Frontal—Age of sepulchral cavity—Caves of Germany and France—General conclusions as to caves—Evidence of progress during Palæolithic Period—Reindeer period in Belgium and France—Cold climatic conditions during the closing stage of Palæolithic Period—Alternations of genial and cold climates in earlier stages of same period—Break between Palæolithic and Neolithic Ages 105-120

CHAPTER VIII.

RIVER-DEPOSITS OF THE PLEISTOCENE PERIOD.

M. Boucher de Perthes' discoveries—Professor Prestwich on origin of the ossiferous and implement-bearing "drifts"—Fluviatile origin of the so-called "drift"—Erosion of river valleys during Pleistocene times—Time required for excavation of valleys—Professor A. Geikie on modern denudation—Flooded condition of Pleistocene rivers—Professor Prestwich on relation between ancient river-gravels and loams—Absence of well-marked river-terraces accounted for—River-ice and ice-floated erratics—Professor Prestwich on climatic conditions implied by Pleistocene river-deposits—Commingling of different groups of mammals—Sir C. Lyell's views—Mr. Darwin on angular gravels of Southern England 121-142

CHAPTER IX.

LOAMY DEPOSITS OF THE PLEISTOCENE PERIOD.

Löss of German geologists—Its distribution throughout Europe—Organic remains of the löss—Dr. Nehring on loamy deposits of Thiede and

Westeregeln—Mammalian and human remains in löss—Changes in composition of löss—River-gravels and lignite underlying löss—Löss of Northern France—Its relation to *Diluvium gris* and *Diluvium rouge*—*Terre à briques* and *Limon grossier*—Fossils of French löss—Belgian löss—Its organic remains—M. Dupont on Belgian löss and associated deposits—*Tchernozem*, or black-earth of Russia—Theories of the origin of löss—Views of Bennigsen-Förder, Hibbert, Gümbel, Lyell, Prestwich, Tylor, A. Geikie, Belt—Murchison on origin of black-earth—De Mercey on origin of French limon—D'Acy's views on same—Baron Richthofen's löss-theory—Mr. Pumpelly's views. Pages 143-168

CHAPTER X.

THE GLACIAL PERIOD.

Early views of glacial phenomena—Agassiz's glacial theory—Glacial phenomena of Scotland—Origin of rock-striæ, *roches moutonnées*, till or boulder-clay, etc.—Intruded till and great erratics—Direction of glaciation in Scotland—Glaciation of Ireland; of English Lake District; of Lancashire; Wales, etc.—Glacial phenomena of north-east of England; of Midland districts and East Anglia—Great erratics—Glaciation of Norway and Sweden; of Finland and Northern Russia; of Germany—Contorted and disturbed rocks under boulder-clay—Great erratics—Direction of the northern *mer de glace*—Course followed by "under-tow" of ice-sheet 169-206

CHAPTER XI.

THE GLACIAL PERIOD—*Continued.*

Ancient glaciers of north and south sides of the Alps, of the Jura Mountains, of the Black Forest, of the Vosges, of the Carpathians, of the Ural, of the Pyrenees and the Cantabrian Mountains, of Central and Southern Spain, of Corsica, of the Apuan Alps, of the Caucasus, of the Lebanon, of the Atlas Mountains—Erratics in the Azores—Limestone-breccias of Gibraltar—Breccias, etc., of Malta—Loam with flints of Northern France—"Head" of maritime districts of the Channel area—Stanniferous gravels of Cornwall—Glacial phenomena of North America—Angular earthy *débris* of North Carolina—Volume of water discharged from ancient glaciers—Quantity of mud in water coming from glaciers—Origin of löss and loamy deposits of Rhine, Danube, etc., of Central Europe—Origin of the Tchernozem or "black-earth" of Southern Russia—Objections to Baron Richthofen's löss-theory—Summary of conditions during Glacial Period. Pages 207-251

CHAPTER XII.

INTERGLACIAL EPOCHS.

Earliest recognition of interglacial deposits—Interglacial beds of Scotland—Sections at Hailes Quarry near Edinburgh—Alternating arctic and genial climatic conditions—Succession of glacial and interglacial deposits in England—Palæolithic implements in interglacial deposits at Brandon, Suffolk—Changes of climate during Glacial Period in British area—Glacial deposits of Scandinavia—Ancient *strandlinier* or horizontal rock-terraces of Norway—Theories of their origin—Their possible interglacial age—Interglacial deposits of Northern Germany—Section at Rixdorf on the Spree—Section at Dömitz on the Elbe—Interglacial beds at Tempelhof—Boring near the Schwielow-See—Traces of interglacial submergence—Glacial and interglacial deposits of Saxony; of Holstein and Denmark—Sand, gravel, and superficial erratics of Northern Europe—Dr. Penck's views of climatic and geographical changes—Preservation of beds under till or boulder-clay 252-296

CHAPTER XIII.

INTERGLACIAL EPOCHS—*Continued.*

Interglacial deposits of Switzerland—Interglacial river-terraces at Camischollas—Glacial and interglacial deposits near Thoron; at Dürnten and Utznach; at the Bois de la Bâtie—Interglacial beds of Northern Italy—Ancient glacier of the Lago d'Iseo—Lacustrine deposits of the Val Borlezza—Deposits in the basin of Gandino—Lignites of Leffe—Interglacial age of the lacustrine deposits of Val Borlezza and Val Gandino—Lacustrine deposits in Val Adrara and Val Forestro—Deposits in the Upper Val d'Arno—Interglacial deposits of Central France—Pumiceous conglomerate and associated deposits at Perrier, near Issoire—Glacial and interglacial deposits in the valleys of the Ain and the Rhone—Successive glacial epochs in the Vosges mountains—Two glacial epochs in the Pyrenees—Interglacial deposits at Gibraltar—Probable interglacial age of similar deposits in Malta 297-330

CHAPTER XIV.

CLIMATIC AND GEOGRAPHICAL CONDITIONS OF PLEISTOCENE PERIOD—SUMMARY.

Climatic and geographical conditions of Europe during Pliocene times—Gradual change of climate and commencement of Glacial Period—Modification of fauna and flora in glacial times—Geographical conditions in Pleistocene Age—Land-connection between Europe and Africa—Continental condition of British area—Dry land in the English Channel—Human relics in Pliocene strata—Cut bones in Italian Pliocene—Human relics in Miocene strata—Geographical conditions in Europe at the beginning of the last interglacial epoch—Migrations of plants and animals—Character of interglacial climate—Geographical conditions at climax of last interglacial epoch—Gradual deterioration of climate—Geographical conditions towards close of last interglacial and beginning of last glacial epoch—Last glacial epoch—Migrations of plants and animals—Final disappearance of great glaciers, etc.—Distribution of interglacial deposits—Interglacial age of Palæolithic man and mammalia of southern group. Pages 331-362

CHAPTER XV.

NEOLITHIC, BRONZE, AND IRON AGES.

Difficulty of ascertaining the relative antiquity of Neolithic relics—The Danish "kitchen-middens"—Views of Worsaae, Steenstrup, and Lubbock—Fauna of the "kitchen-middens"—Neolithic man—Conditions of life—Shell-mounds of Britain and France—Lake-dwellings of Switzerland—Dr. Keller on various forms of lake-dwellings—Human relics—Remains of plants and animals met with in ruins of lake-dwellings—Conditions of life—Passage from the Neolithic through the Bronze into the Iron Age—Relics of Neolithic and later archæological periods in other regions—"Long-heads" and "broad-heads" of British barrows—Celtæ, Belgæ, and Germani—Contrasts between Palæolithic and Neolithic Ages . . 363-380

CHAPTER XVI.

POSTGLACIAL AND RECENT DEPOSITS OF THE BRITISH ISLANDS.

Physical conditions of late glacial times—Scottish Postglacial beds—Raised-beaches—Estuarine and river-deposits—Organic remains—

Submarine forests and peat—Buried forest, etc., of Carse of Gowrie, etc.—Succession of deposits—Glacial and late glacial accumulations of 100-feet terrace—Postglacial river detritus—Ancient land-surface and vegetable remains under Carse-clays—Origin of Carse-clays—Connection of these clays with torrential gravels—Postglacial deposits of the Forth valley—Vegetable remains—Kitchen-middens of 45-50-feet beach—Postglacial deposits of the Montrose Basin—Succession of changes—Date of last elevation of land Pages 381-406

CHAPTER XVII.

POSTGLACIAL AND RECENT DEPOSITS OF THE BRITISH ISLANDS—*Continued.*

Larger size of Scottish rivers in Postglacial times—Local glaciers then reached the sea-level—Recent glaciation in mountain-valleys of Scotland—Contrasts between glacial phenomena of the Ice Age and Postglacial times—Examples of postglacial moraines—Interval between the close of the Glacial Period and the reappearance of local glaciers in Postglacial Period—Scottish raised-beaches—Peat-bogs of inland districts—Buried forests in peat-bogs—Correlation of these with the submarine forests and peat of the maritime districts—Age of the Scottish peat-bogs—Alluvial deposits of Scotland—Their organic remains—Correlation of archæological epochs with geological stages in Postglacial history of Scotland . . 407-429

CHAPTER XVIII.

POSTGLACIAL AND RECENT DEPOSITS OF THE BRITISH ISLANDS—*Continued.*

Submerged forests of English coast—Unconformity between Glacial and Postglacial accumulations—Submarine forests of Lancashire and Cheshire—Succession of deposits—General conclusions as to conditions of accumulation—Postglacial and recent deposits of Cornish coast—Section of Happy Union Works, Pentuan—Sections of Lower Pentewan Work—Section at Huel Darlington Mine—General conclusion as to the succession of changes—Sunk forests and buried peat of the Fenland—Relation of Fen-beds to glacial deposits—Character of Fen-beds—General conclusions as to conditions under which they were accumulated . . . 430-450

CHAPTER XIX.

POSTGLACIAL AND RECENT DEPOSITS OF THE BRITISH ISLANDS—*Continued.*

Correlation of English Postglacial accumulations—Résumé of the evidence—Raised-beaches of English coasts—Postglacial accumulations of inland districts—Their unconformability to Glacial and Palæolithic deposits—English rivers of larger volume in Postglacial times—Lacustrine alluvia and peat-bogs of England—Their organic remains—Succession of forest-layers in English peat—Arctic flora at Bovey Tracey—Postglacial mammals of England—Postglacial and recent deposits of Ireland—Submarine trees and peat—Raised-beaches—Neolithic kitchen-middens—Successive tiers of trees in bogs of inland districts—Mr. Kinahan's observations on succession of changes which these imply—Human relics in Irish bogs—Postglacial mammalia . . . . . Pages 451-463

CHAPTER XX.

POSTGLACIAL AND RECENT DEPOSITS OF THE CONTINENT.

Postglacial and recent deposits of Norway and Sweden—No direct passage from Glacial into Postglacial accumulations—Postglacial shelly clays, etc.—Character of the molluscan fauna—Contrast between shelly clays of the east of Sweden and those of Western Sweden and Norway—Height of Swedish and Norwegian shell-banks above sea-level—Postglacial freshwater and marine deposits of Finland—Unfossiliferous clay and sand above shelly clays of Norway and Sweden—Postglacial erratics resting on shelly clays of Eastern Sweden—General conclusions—Submerged peat of Scania—Raised-beaches of same region—Submerged peat and trees of Denmark; of Schleswig-Holstein; of East Friesland and Holland; of Flemish coast; of Somme Valley; of Normandy and Brittany; of Arcachon and Biarritz—Age of the submerged forests of the Channel area—Peat-bogs of Denmark; of Norway—Rate of growth of peat—Arctic flora in Postglacial deposits of Southern Sweden, of Brandenburg, and other parts of Germany—Peat of Champagne, its organic remains—Peat-bogs in other regions of Europe—No trace of Palæolithic man in any Postglacial accumulations—Postglacial deposits of Spitzbergen. 464-498

CHAPTER XXI.

CLIMATIC AND GEOGRAPHICAL CONDITIONS OF POSTGLACIAL AND RECENT PERIODS—SUMMARY.

Genial conditions in Southern Scandinavia—Mediterranean molluscs in Northern Seas—Southern forms in Gulf of St. Lawrence—Condition of Northern Sea in latest glacial epoch—Immigration of Southern species in postglacial times—Migration of arctic flora in late glacial and early postglacial times—Edward Forbes on origin of British fauna and flora—Contrasts between Britain and Ireland—Large postglacial lake occupying bed of Irish Sea—Ireland derived its fauna and flora partly by way of Scotland—Genial climatic conditions—Former greater range of forests—Trees in peat of Færöe Islands and Norway—Peat with pine on shores of Wellington Channel—Origin of floras of Færöe Islands, Iceland, and Greenland—Former connection of those regions with Europe in postglacial times—Traces of former genial conditions in Kurland—Gradual disappearance of genial climate and submergence of land in north and north-west—Formation of 50-feet beach of Scotland—Local glaciers and swollen rivers—Cold and humid conditions, and increase of peat-bogs—Retreat of sea and amelioration of climate—Second great forest-growth—Second peat-forming period—The Present—Southern Europe in postglacial times—Date of advent of later Prehistoric races. Pages 499-538

CHAPTER XXII.

CONCLUSION.

Résumé of results—Identity of Pleistocene or Quaternary Period with Preglacial and Glacial times—Alternations of cold and genial climates in Pleistocene Period—Testimony of fauna and flora—Palæolithic man lived through the Pleistocene Period—Testimony of the Pleistocene river-deposits as to climatic conditions—Evidence supplied by cave-accumulations—Glacial and Interglacial accumulations contemporaneous with river-gravels, etc., and cave-deposits—Distribution of ossiferous and Palæolithic river-deposits—Last cold epoch of Glacial Period closes the record of Pleistocene times—Palæolithic implements in Interglacial deposits at Brandon; in Pliocene or early Pleistocene beds of St. Prest—Pliocene and Miocene man—What became of Palæolithic man—Professor Dawkins's views—Objections to his hypothesis that the Eskimo are of the same race as Palæolithic man—Views of M. Quatrefages and other French savants—Climatic and Geographical conditions of Postglacial Period—Age of the archæological periods—Dr. Croll's theory of the cause of glacial and interglacial climatic changes—Conclusion . Pages 539-562

APPENDIX.

PAGE
Note A.—Table of Sedimentary Formations . . . 563
Note B.—Map of Europe at the Climax of the Ice Age . . 564
Note C.—Europe in Early Postglacial Times (First Age of Forests) 568

LIST OF PLATES.

PLATE A.—Palæolithic Implements . . *To face page* 12
PLATE B.—Map of Glacial System of Lake Iseo „ 304
PLATE C.—Neolithic Implements . . „ 372
PLATE D.—Map of Europe at the Climax of the Ice Age . . . . „ 564
PLATE E.—Europe in Early Postglacial Times (First Age of Forests) . . „ 568

PREHISTORIC EUROPE.

CHAPTER I.

INTRODUCTORY.

THERE is no chapter in the geological history of Europe more interesting than that which deals with the physical aspect and condition of our continent in prehistoric ages. What appearance did our mountains and valleys then present? Was Europe as extensive in those old times as it is to-day? Are the shores upon which our seaport towns are built the same as those along which wandered the earliest races of mankind? With what tribes of animals and plants were our ancient predecessors associated, and under what conditions of climate did they live? To answer all these and other subsidiary questions as fully as one might, would involve the consideration of a much wider range of evidence than it is possible to discuss adequately in the compass of these pages; nevertheless such an outline of facts and inferences may be given as shall serve to afford some notion of the mode in which a geologist views the subject. It is as well to state at once, however, that there is a large class of facts which might properly enough come under our attention in a work like the present, but which I do not purpose to treat of specially. These have reference to the more or less local changes and modifications of the coast-line, brought about by the erosive and denuding action of waves, breakers, and tidal currents, and by the increase of deltas. Neither do I mean to give any account of those limited earth-movements, which have here and there raised and depressed certain maritime districts of no great extent. Such geographical changes as I shall refer to are those which have aided most considerably in producing the present distribution of our fauna and flora. And so with changes of climate, attention will be confined to those which can be proved to have been more or less general, and which in conjunction with great oscillations of the sea-level have left abiding traces, not only in the living world, but upon the features of the land itself.

It is well known that when we try to trace the history of any nation back into the past, we sooner or later come to a period of myth and tradition, beyond which all seems impenetrably dark. If, for example, we take the case of Britain, how meagre, doubtful, and obscure, does the story become after it has carried us back to the days of the Romans! We may be able to determine with more or less probability whence the people came who were natives of Britain at the time of the Roman invasion; but beyond that, who can venture into the dark and hope to pick his way securely? It is just here, however, where myth and tradition fail us, that the archæologist and geologist step forward to point out that all is not so irrecoverably lost as historians at one time believed. We know now that many long centuries before the advent of the Romans, our islands were occupied by a people whose knives and swords were fashioned of bronze; we know further that this people was preceded by a race or races ignorant of the use of metals, who lived during several considerable changes of climate and oscillations of the sea-level; and we have also learned that at a still remoter period, our country and the neighbouring parts of Europe were tenanted by tribes of yet ruder barbarians, during whose occupancy several extensive geological mutations occurred. It is from a consideration of the extraordinary vicissitudes of climate and the very considerable changes in the configuration and outline of the land which have taken place within the human era, that geologists have been led to assign a far higher antiquity to man's first appearance than the old chronologies would allow.

When the announcement was made some years ago that rude stone implements of undoubted human workmanship had been discovered in certain alluvial deposits in the valley of the river Somme, under circumstances which argued for the human race a very great antiquity, geologists generally received the news with incredulity. That the advent of man was an occurrence merely of yesterday, as it were, and a matter to be discussed properly by chronologists and historians alone, most of us until lately were taught to believe. So ingrained, indeed, had this belief become, that although evidence of the antiquity of our race similar to those subsequent French discoveries, which succeeded at last in routing the sceptical indifference of geologists, had been noted from time to time in England, and especially by Schmerling in Belgium, yet it was only noted to be explained away, and in point of fact was persistently neglected as of no importance.

Doubt had been cast upon the conclusions drawn from certain evidence supplied by the English caves, and it was not till 1858, when Brixham Cave was explored under the auspices of the Royal and Geological Societies of London, that English geologists abandoned their preconceived notions as to the improbability of man and many extinct mammals having co-existed in Britain. Meanwhile, M. Boucher de Perthes, a zealous and enthusiastic French antiquarian, had been insisting for more than twenty years upon his discovery of "antediluvian" human implements and mammalian remains in undisturbed natural accumulations of loam, sand, and gravel near Abbeville. But all his insistence had been in vain—his fellow-countrymen paid little or no regard to his tale of wonder. It was not till 1859 that attention was at last directed to the enthusiastic Frenchman's discoveries by Dr. Falconer, and later on by Mr. Prestwich, Mr. Evans, Sir C. Lyell, Sir J. Lubbock, and other

English geologists, who were enabled to confirm to the fullest extent Boucher de Perthes' observations.

It is curious to reflect now that while British geologists were flocking to the Somme valley to inspect the discoveries there, similar "finds" of human implements and associated mammalian remains had already been made in England itself many long years before—namely in 1715, 1800, and 1836. But these had attracted no attention, and indeed had been completely forgotten. Let it be remembered also that to the late Dr. Schmerling of Liège belongs the honour of having been the first to show (in 1833), that man and the extinct mammalia were contemporaneous, although his work lay neglected and ignored for a quarter of a century. Such it would seem is the fate of those who publish "unwelcome intelligence, opposed to the prepossessions of the scientific as well as of the unscientific public."[1] The Rev. Mr. MacEnery had arrived about the same time as Schmerling at similar results, and was engaged in the preparation of a memoir descriptive of his discoveries, when death cut short his labours, and his MS. was lost sight of for many years. Both Schmerling's and MacEnery's work was confined to cave exploration, but Boucher de Perthes we have to thank for opening our eyes to quite another line of evidence in favour of the great antiquity of our race. Since the recognition of the importance of his discoveries, rude stone implements commingled with the remains of extinct mammals have been found in British caves, and in certain ancient river-deposits in the south-eastern counties of England, as also in similar positions in many localities on the Continent; so that we no longer doubt that, in ages long anterior to our own, certain tribes of cave-dwelling savages, and many large mammalian animals, which are now either locally or wholly extinct, were in joint occupation of Britain and the Continent. And the more closely the evidence is considered, the farther into the past does the period at which these cave-men lived seem to recede.

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[1] Lyell, *Antiquity of Man*, 4th edit., p. 71.

CHAPTER II.

ARCHÆOLOGICAL PERIODS.

Classification of Human Relics—Stone Age, Bronze Age, and Iron Age—Phases of Civilisation — Gradual transition from Stone Age into Bronze Age, and Bronze Age into Iron Age—Palæolithic and Neolithic Periods—Palæolithic Implements—Classification of Palæolithic Cave-relics—Conditions of life in Palæolithic Period—Human Remains—Break in Succession between Palæolithic and Neolithic Periods.

EVERY one is aware that human relics of great antiquity occur, more or less abundantly, in many parts of Europe. Some of these can be referred to the early dawn of historical times; others have been hesitatingly assigned to still more remote periods, of which the only records that survive are supposed to be certain semi-mythic legends and poetical traditions; and how much of these we should believe it is hard to say. There are many antiquities, again, that belong to a time so far removed from our own, that history and tradition alike fail to tell us anything about them. We find only the relics themselves, and from these, and their position and mode of occurrence in or upon our soils and subsoils, we are left to discover what we can of the life-history of the people to whose former presence they testify, and to gather what information we may in regard to the physical conditions under which these people lived, and the geological mutations that have taken place since they passed away.

The antiquities referred to are of many kinds—dwelling-places, sepulchral and other monuments, forts and camps, and a great harvest of implements and ornaments of stone and metal. In seeking to classify these relics and remains according to their relative antiquity, archæologists have selected the implements and ornaments as affording the most satisfactory basis for such an arrangement, and they divide prehistoric time into three periods, which are termed respectively the Stone Age, the Bronze Age, and the Iron Age. Of these periods the earliest was the Stone Age, when implements and ornaments were formed exclusively of stone, wood, horn, and bone. The use of metal for such purposes was then quite unknown. To the Stone Age succeeded the Age of Bronze, at which time cutting-instruments, such as swords and knives and axes, began to be made of copper, and an alloy of that metal and tin. When in the course of time iron replaced bronze for cutting-instruments, the Bronze Age came to an end and the Iron Age supervened. This classification has received the strongest support from independent geological investigations, and is now generally accepted. But apart altogether from these and other considerations, the arrangement suggested by archæologists must commend itself to every one who shall give the subject any attention. Those at all events who believe in the progressive development and improvement of our race will readily admit that a long time must necessarily have elapsed before men acquired the art of reducing metals from their ores. It is most natural to suppose that in the earliest times stones chipped or ground to an edge would continue for an indefinite period to be used for all kinds of purposes. The smelting of ores implies a further advance on the road to civilisation. But it seems at first sight strange that the use of bronze should have preceded that of iron, the ores of which are so much more abundantly and widely diffused than those of copper and tin. The former, however, though more plentiful, are, as Sir John Lubbock remarks, much less striking in appearance than those of copper. Moreover, while copper is often found in the metallic state, iron very seldom occurs in that condition, being met with only in meteorites. The extreme malleability of copper would also be as much an advantage as the intractable nature of iron would be a disadvantage to the primitive makers of weapons and tools.

How the alloy of tin and copper came first to be used we can only conjecture. Sir John Lubbock suggests that the ores of tin may have early attracted notice on account of their great heaviness. However this may be, it was probably quite by accident that an alloy of tin and copper came to be made. But when it was found that such a mixing of the metals produced a material much better adapted for cutting-instruments, we may be sure that the results of such a happy accident would soon become noised abroad.

From the fact that implements of pure copper are rarely met with in Europe, it has been inferred that the art of making bronze was introduced into our continent before copper came to be used. The rarity of copper implements, however, may be partly owing, as General Lane Fox has suggested, to their having been subsequently converted into bronze, when the advantageous properties of the alloy came to be generally recognised.

Just as it might have been inferred that the age in which bronze implements were made would prove to be of more recent date than the primitive period when man fashioned all his weapons and tools of stone, horn, bone, and wood, so we might reasonably conclude that the art of working intractable iron would be acquired later on than that of beating native copper into shape, and of forming instruments of the easily-cast alloy of copper and tin. And this, as archæologists assure us, is precisely what took place—an Age of Iron succeeded to one of Bronze.

From these few remarks it will be seen that the archæological periods are simply so many phases of civilisation, and it is conceivable that Stone, Bronze, and Iron Ages might have been contemporaneous in different parts of one and the same continent. But although there is nothing inherently improbable in such a supposition, nevertheless it has been perfectly well ascertained that, so far as Europe is concerned, a true Stone Age to which the use of metals was quite unknown endured throughout the continent for a period so prolonged that we can but vaguely grasp its immensity. And it has likewise been proved that long after the knowledge of bronze had become general in Europe, our ancient predecessors continued through many centuries perfectly ignorant of the use of iron.

It is not to be supposed, however, that the close of the Stone Age was marked by the total abandonment of stone for bronze implements. On the contrary, stone continued to be used for some kinds of implements far on into the Bronze Age, and even down to historic times. Indeed the substitution of metal for stone cutting-instruments might have been very slowly effected in some parts of Europe; and one can readily believe that in certain countries bronze might come to be almost exclusively employed for such purposes, while elsewhere it remained much longer either only partially in use or quite unknown. One can hardly doubt, for example, that long after the natives of Southern Europe had commenced to cut and stab their enemies with bronze swords and daggers, and to decorate their own persons with trinkets of the same alloy, the inhabitants of the wild mountain-valleys of Scotland and its outlying islands might still be living in a "Stone Age." It must be understood, therefore, that there was no abrupt transition from an age in which only stone implements were used to one in which bronze was exclusively employed. Moreover, it would be a mistake to suppose that the Stone and Bronze Periods of one country are necessarily strictly contemporaneous throughout with the similar stages in the archæological history of all other parts of Europe. It is quite possible that the closing scenes of the true Stone Age in North-western Europe may be synchronous with the earliest stage of the Bronze Period in the south-east of the Continent. This would necessarily follow if it be the case, as many archæologists believe, that the knowledge of metals was introduced from the East. The difference in point of antiquity, then, between the commencement of the Bronze Age in two such countries as Greece and Britain, let us say, would simply be measured by the length of time the natives of the latter country remained ignorant of bronze after those of the former had acquired a knowledge of that alloy. But that time, however long it may have been, is much too trifling to be taken into consideration when periods of such duration as those of archæology are being dealt with. Moreover, the passage from the true Stone Age into the Bronze Age may have been actually somewhat sudden, if, as is not altogether improbable, metallurgical knowledge came in with one of those great folk-waves which have successively swept over Europe. But in whatever manner that knowledge was acquired it is certain that, long after cutting-instruments of bronze had come into use in every region of our continent, stone implements continued to be employed for many purposes, and are found commingled with relics of bronze in the "finds" that belong to that period. Thus the presence of a single bronze weapon, if it occur along with relics of stone in such a way as to leave no doubt that it was buried along with them, is sufficient proof that the relics in question cannot pertain to the true Stone Age. And for the same reason we must not assign any assemblage of bronze implements to the Bronze Age, however numerous they may be, if a single iron implement has been found in like manner along with them. For just as stone implements were largely made use of long after the knowledge of casting bronze had been acquired, so bronze continued to be employed, especially for trinkets and ornaments, far on into the true Iron Age.

With the aid of these ancient stone and metallic implements it has now become possible to ascertain the relative age of many other interesting objects of antiquity, such as stone circles, and other megalithic monuments, barrows, forts, camps, dwelling-places, and so forth. For example, if upon examining some sepulchral chamber, such as usually occurs in the so-called barrows, we should find only bronze implements, or a mixture of these with relics of stone, and if there was no appearance of the place ever having been disturbed since the stones and earth were heaped above it, we should conclude that the interment belonged to the Bronze Period. But if one or more instruments of iron occurred amongst the others we should refer the burial to a later age.[1] Our conclusion would be still further strengthened if, after examining a large number of similar interments, we should find that they all possessed many features in common. Again, should our explorations discover not a trace of either iron or bronze, and should the implements and ornaments we come upon consist exclusively of stone, horn, and bone, the presumption will be in favour of the true Stone Age of the "find." And this presumption will gather strength according to the number of those discoveries we make. It would be an additional argument in favour of such "finds" pertaining to the Stone Age if amongst the implements cutting-instruments were well represented. Of course there are other and additional methods of ascertaining the relative antiquity of these and prehistoric remains generally, but the methods referred to will necessarily come before our attention when we are considering the mode of occurrence of these remains from a geological point of view.

With the Bronze and Iron Ages the geologist has comparatively little to do; for we shall find in the sequel that the Europe of the later Bronze Period was very much the same as it is to-day. No great geological revolutions have come about in our continent since then, and hence these pages will be occupied chiefly with an account of the climatic and geographical changes which supervened during the true Stone Age.

It has been found necessary within recent years to subdivide the Stone Age into two periods, called respectively the Old Stone and New Stone Ages; or, to employ the terms suggested by Sir John Lubbock, and now generally adopted, the Palæolithic and Neolithic Periods. The stone implements belonging to the older of these periods show but little variety of form, and are very rudely fashioned, being merely roughly chipped into shape, and never ground or polished. The weapons and instruments of the later period, on the other hand, are extremely varied in form. They are often beautifully finished, and frequently ground to a sharp point or edge, or polished all over. But the simplicity and rudeness of its implements are by no means the only distinguishing characteristic of the Palæolithic Period. We shall see in subsequent chapters that the relics of this earlier Stone Age are most frequently met with in positions that plainly argue for them a much greater antiquity than can be assigned to the oldest remains of Neolithic times. And not only so, but Palæolithic man was associated with many great mammals that became either locally or wholly extinct before the appearance of his Neolithic successor in Europe. The animals with which Neolithic man was contemporaneous, belong, for the most part, to species that are still indigenous to our continent—the forms in short are familiar, although not a few of them are now locally extinct, such as the wild-boar, wolf, and beaver in Britain, all of which, as is well known, have vanished within historic times.

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[1] It must be borne in mind, however, that now and again a commingling of implements pertaining to two or more ages may have been brought about in cases where the same spot was utilised for interments at different times. Thus it is known that not unfrequently interments of the Stone Age have been disturbed by subsequent burials in the Bronze and Iron Ages. Hence sometimes we may have implements belonging to distant and distinct periods confusedly commingled in one and the same place, just as if they had all been contemporaneous.

Some characteristic forms of Palæolithic implements[1] are shown in the accompanying Plate A, which may be compared with the drawings of Neolithic implements in Plate C, Chapter XV. Fig. 1 (Plate A) represents an implement from the lowest deposit in Kent's Cave, Devonshire. It has been formed by operating on a well-rolled nodule of flint, a portion of the original surface of which is seen at the convex butt-end of the implement.[2] The other drawings (Figs. 2-8) represent various forms of Palæolithic implements. Fig. 2 is a flint implement found by Mr. Prestwich at a depth of about 20 feet in ancient river-gravel deposits at St. Acheul, near Amiens. It represents a form commonly met with in those beds. Figs. 3 to 8 are all from caves in the Dordogne, and are copied from *Reliquiæ Aquitanicæ.* Fig. 3 was probably used as a drill for piercing holes. Fig. 4 may have been a lance-head; Fig 5 is a lanceolate tool or weapon of some sort; and Fig. 6 is evidently a saw. Fig. 7 is supposed to be a harpoon-head, "carved out of antler, broken at one end, and furnished with a lancet-shaped point (imperfect), and a single barb at the other." The carvings represent a horse's head, a deer (the head and neck alone being carefully executed), and what appears to be intended for a fish. Fig. 8 is the handle of a poniard, shaped as a reindeer. The original illustration in *Reliquiæ Aquitanicæ* shows the whole weapon—handle and blade—which are cut out of the beam of a reindeer's horn. (With the exception of Fig. 1, which is half the size of the original, all the drawings represent the actual dimensions of the objects portrayed.) With regard to the mode in which these and others were used, only conjectures can be offered. Some may have been hafted like the stone axes of certain modern savages; while others may have been held in the hand, and used as scrapers for dressing skins, for smoothing wooden handles, and horns, and bones. With some, Palæolithic man may have grubbed up esculent roots, and others he may have employed as wedges for splitting wood; while some of the smaller ones, Dr. Evans suggests, may have been missiles. The larger ones (Fig. 1, Plate A), which occur sometimes plentifully in certain ancient river-gravels, have been supposed by Professor Prestwich to be possibly implements used for cutting holes in the ice when the rivers were frozen over, for the purpose of fishing or of obtaining water. Besides these worked tools, Palæolithic man also used certain stones, such as granite, indurated red sandstone, and quartzose grit, as hammers or pounders, probably for mashing roots, breaking and crushing bones, and other purposes. Such stones usually show the marks of battering on one or more faces.

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[1] For a particular account of Palæolithic and Neolithic implements, see Dr. Evans's well-known work on *Ancient Stone Implements.* Excellent figures are also given in *Reliquiæ Aquitanicæ;* Sir J. Lubbock's *Prehistoric Times;* Lyell's *Antiquity of Man;* and other general treatises.

[2] This figure is copied from an interesting paper by Mr. Pengelly in the *Journal of the Plymouth Institution,* read in 1875.

It is remarkable that nearly all the Palæolithic worked implements are formed of flint and chert, and chiefly of the

PLATE A
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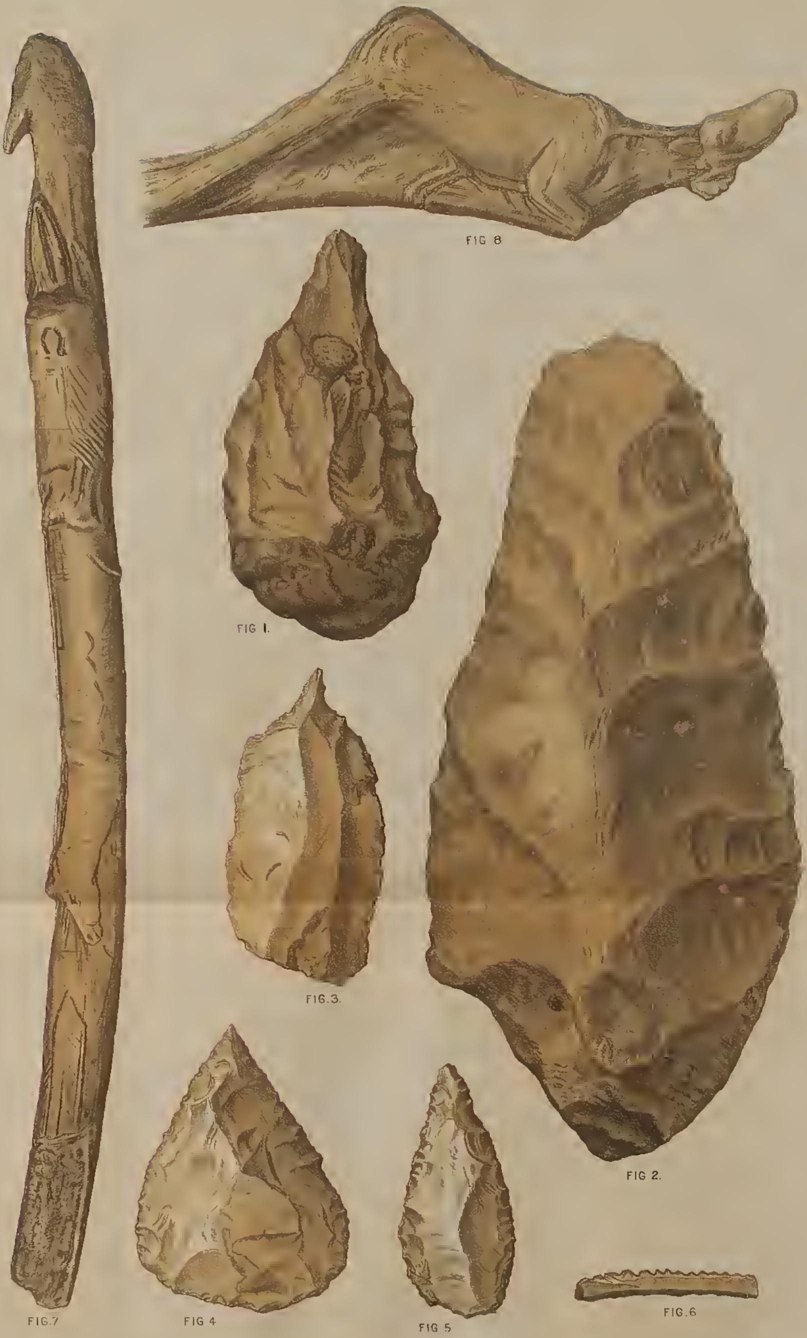

FIG 8

FIG 1.

FIG 2.

FIG.3.

FIG.7

FIG 4

FIG 5

FIG.6

PALÆOLITHIC IMPLEMENTS

former; the instances of any other kind of stone being extremely rare. In this respect they differ from those of Neolithic age, which are formed of many varieties of hard stone, although flint from its extremely tractable nature was still in general demand, especially for arrow-heads, and any instrument for which a cutting edge or sharp point was desired.

Other implements of Palæolithic age are formed of bone and horn. Among these are harpoon-heads, barbed on one or both sides, awls, pins, and needles with well-formed eyes. But by far the most noteworthy objects of this class are the fragments of bone, horn, ivory, and stone, which exhibit outlined and even shaded sketches of various animals. These engravings have been made with a sharp-pointed implement, and are often wonderfully characteristic representations of the creatures they portray. The figures are sometimes single, in other cases they are drawn in groups. We find representations of a fish, a seal, an ox, an ibex, the red-deer, the great Irish elk or deer, the bison, the horse, the cave-bear (Fig. 1), the reindeer (Fig. 2), and the mammoth or woolly elephant. Besides engravings, we meet also with sculptures, a good example of which is shown in Plate A, Fig. 8.

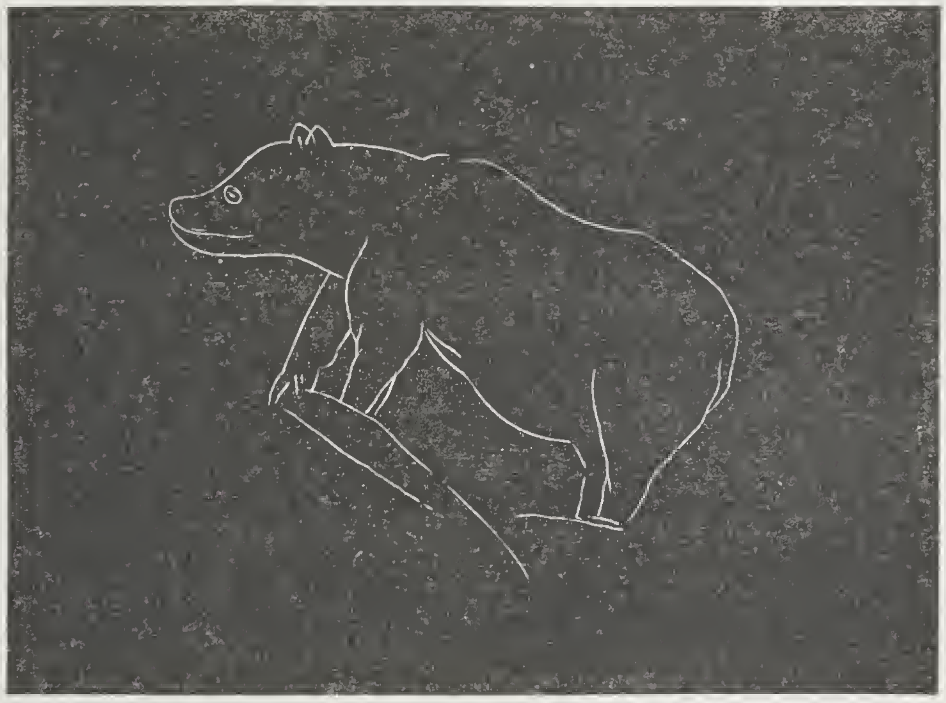

Fig. 1.—Etching of Cave-bear found in the Cave of Massat (Ariége), $\frac{1}{2}$.

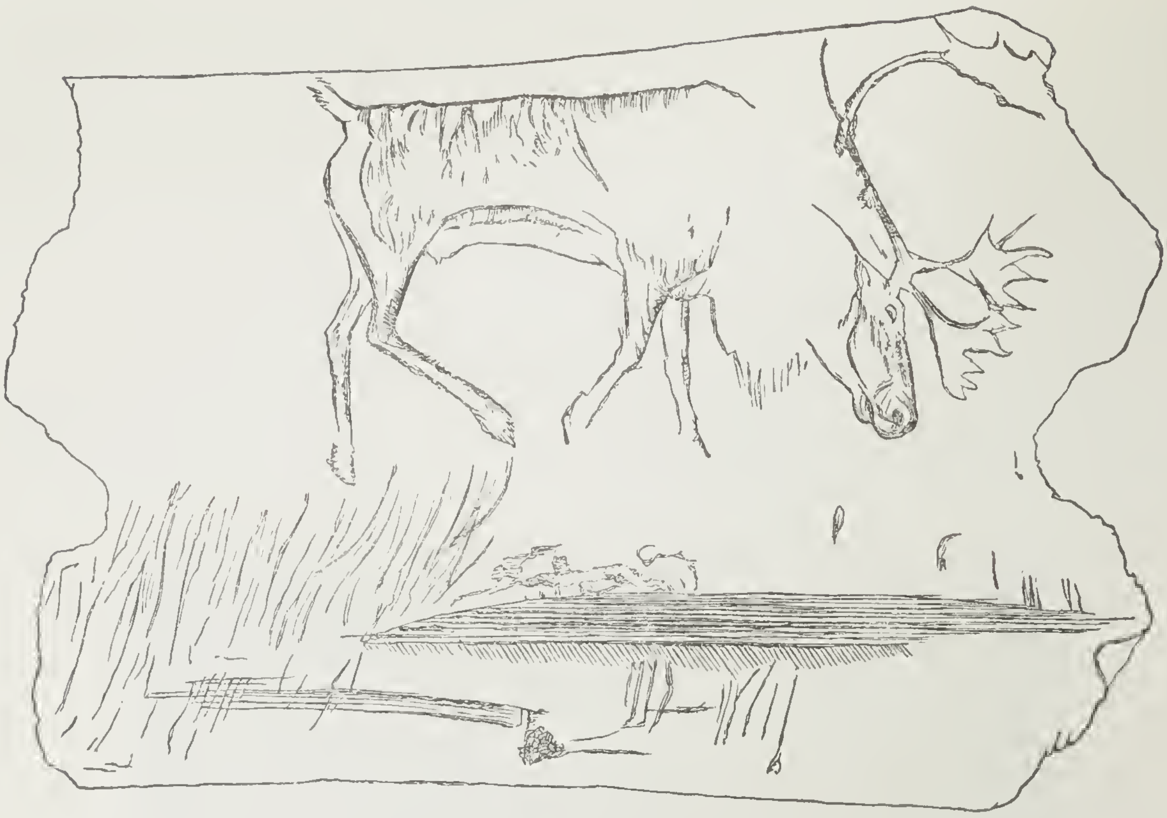

Fig. 2.—Reindeer, engraved on antler, $\frac{2}{3}$. From the Kesserloch, Schaffhausen (Heim).

It is impossible to say to what use all these objects were put. Some of them may have been handles for knives, while others are mere fragments, and only vague guesses can be made as to the nature of the original implements. It is highly probable, however, that many of these works of art may have been designed simply as such, for the pleasure and amusement of the draughtsman and his fellows. A curious carved implement of reindeer horn, figured by M. Dupont, is termed by him a "bâton du commandement," but is perhaps, as Professor Dawkins has suggested, an instrument used for straightening arrows, like the sculptured "arrow-straighteners" of the Eskimo. Besides these objects, "whetstones" have now and again been met with in Palæolithic "finds," and these are supposed to have been used for imparting the final smoothing and polishing to the horn and bone implements, and for giving a sharp point to such as required it. Pieces of iron-ore (red hematite and oligiste), which occur now and again associated with Palæolithic remains, are supposed by some to have been used as pigments for painting the body. Other traces of personal decoration are found in the presence of shells and teeth of various wild animals, which have been drilled evidently for the purpose of being strung and used as bracelets or necklaces.

The implements we have been referring to unquestionably belong to very different stages of the Palæolithic Period. The simple forms and rude finish of the worked flints seem to indicate a low type of barbarism, but some are more primitive-looking than others. The more primitive forms are now and again found in cave-deposits in positions which prove them to belong to a very early stage of the Palæolithic Period, while weapons and tools of more varied design and better make occur at higher levels in the same caves. From this it may perhaps be inferred that some progress took place even in Palæolithic times. Attempts have indeed been made to classify the cave-relics according to their prevailing characteristics. Thus De Mortillet has arranged the caves of France in four groups, each of which is distinguished by certain features which are more or less peculiar to the implements that belong to it. In his classification we find that the oldest group embraces those caves which contain what appear to be the most primitive-looking implements, and in which worked bones are rarely or never present. Each of the later groups has its distinguishing characteristics, but it is not needful for the purpose I have in view to mention these in detail. It is enough to say that, while implements of bone and horn are scarce, and no engraved objects occur in the second group, in the third group lance- or dart-heads and other instruments of horn and bone are not only far more numerous, but some of these are engraved with the representations of animals. In the fourth and youngest group of caves works of art are somewhat common. It is from the caves of this last group that the most interesting engravings and carvings have been obtained. Whether this classification will ultimately be accepted in its entirety may be doubted, but it appears in the main to be so reasonable that it has commended itself to many of the most eminent archæologists.

But although it cannot be questioned that some of the tribes or races of Palæolithic times were a little farther advanced than others—so far at least as the fashioning of their implements is concerned—it does not necessarily follow that the men who used the better-made instruments always succeeded in time to those whose implements are somewhat ruder. It is conceivable that they may have lived contemporaneously in different parts of the Continent. "For," as Professor Boyd Dawkins remarks, "there is no greater difference in any two of the Palæolithic caves than is to be observed between those of two different tribes of Eskimos, while the general resemblance is most striking. The principle of classification by the general rudeness assumes that the progress of man has been gradual, and that the rude implements are therefore the older. The difference, however, may have been due to different tribes or families having co-existed without intercourse with each other, as is now generally the case with savage communities; or to the supply of flint, chert, or other materials for cutting-instruments being greater in one region than another." However this may be, it seems at first sight not unreasonable to believe that the artistic people, at all events, who occupied their leisure time in carving and engraving those wonderful life-like representations of animals, must belong to a later date than the savages who have left nothing behind them save flint implements of the rudest form and a few simple relics of bone. Nevertheless, it is not impossible that artistic and non-artistic tribes may have co-existed during Palæolithic times in Europe. Sir John Lubbock reminds us that "there are still instances among recent savages of a certain skill in drawing and sculpture being accompanied by an entire ignorance of metallurgy." And he refers particularly to the case of the Eskimo, many of whose bone implements are covered with sketches, representing animals such as reindeer, geese, and dogs; hunting-scenes, houses, boats, and other subjects. The contrast between the artistic and non-artistic relics of the Old Stone Period, therefore, may point rather to ethnological peculiarities than to any difference in the relative antiquity of the remains. But even with all these possibilities kept in view, there are certain other circumstances which lead to the

45

conclusion that the artistic tribe or people really pertained to the closing stage of the Palæolithic Period. The consideration of this question, however, must be deferred to a subsequent chapter.

Fragmentary as are the relics of the Palæolithic Period, they yet enable us to form certain conclusions as to the conditions of life in that far past age. The men who carved the bone and ivory implements appear to have been a race of fishers and hunters. The reindeer, the musk-sheep, the mammoth, and other animals, were slain by them in the chase, and they probably clad themselves in the skins thus obtained. No trace of any vestment has been preserved, as indeed could hardly have been expected, but the presence of numerous bone needles shows that tailoring of some kind was in vogue. The bone awls were probably used for piercing holes in the tougher skins, an operation for which perhaps the needles were hardly strong enough. The latter would thus be used simply for carrying the thread, which, on the analogy supplied by modern races like the Eskimo and the Lapps, we may reasonably conjecture was formed of sinews. A bone pin (3¾ inches long), which was found in Kent's Cave, is supposed by Dr. Evans to have been employed as a fastener of the dress. It bears a high polish, he says, as if from constant use. It is probable also that the artistic tribes wore gloves, for we have what appears to be the representation of a long glove with three or four fingers, etched upon the canine tooth of a bear found in one of the caves of the Pyrenees. The earlier Palæolithic races—those who occupied North-western Europe before the appearance of the art-loving people—have left nothing to show that they were acquainted with the art of tailoring. All that we know of them in fact is that they used rudely-worked flints, and lived on the proceeds of the chase.

We have good reason to believe that the Palæolithic carvers and draughtsmen, notwithstanding their artistic ability, yet lived in a low state of barbarism. There is nothing to indicate that they cultivated the ground, and they seem to have had no domesticated animals. Neither is there any unequivocal proof forthcoming that they were acquainted with the potter's art. M. Dupont has indeed recorded the occurrence in certain Belgian caves of coarse unbaked pottery associated with Palæolithic implements, while M. Fraas has described a similar occurrence in a cave near Blaubeuern in Würtemberg, and M. de Ferry has noted the like in the cave of Vergisson (Saône-et-Loire). The caves of Chiampo and Laglio in the north of Italy are also said to have yielded Palæolithic pottery. It is probable, however, that in all these cases the potsherds are accidentally present, and really belong to a later date than the Palæolithic implements. Certain it is that no trace of pottery occurs in the Palæolithic cave-deposits of England or of Périgord—and those of the latter have yielded the relics of the artistic people in greater abundance than elsewhere. In the caves of the south of France the carved and worked implements are not only very numerous, but they attain a considerably higher degree of finish than the similar relics which occur in the Belgian caves. It would be strange, therefore, if the occupants of the latter should have been familiar with an art which was totally unknown to the more advanced tribes in the south of France. Moreover, if it be true (as I will by and by endeavour to prove was the case) that the last occupation of the Belgian caves dates back to earlier times than that of the caves of Périgord—that, in fact, the artistic folk migrated southwards from England and Belgium to France, carrying their simple arts with them, it would be more than strange if they had left that of the potter behind. So useful an art once acquired was certain never to be lost again. For the present, then, it seems most reasonable to conclude with Sir John Lubbock and others that Palæolithic man appears to have been unacquainted with the art in question.

Whether the tribes of the Old Stone Period had any polity or social organisation we cannot tell. Some writers have indeed supposed that the more richly engraved and carved implements were state arms, and these, it has been conjectured, might belong to chiefs. But all this is mere guess-work. Again, it has been inferred from the fact that ornaments, implements, and arms have been found in association with certain skeletons which seem to have been interred in late Palæolithic times, that the artistic people had some belief in a future state, and looked forward to happy hunting-grounds beyond the grave. It has even been suggested that some of the small perforated objects found in many Palæolithic deposits may have been worn round the neck as amulets, thus suggesting the existence of a belief in unseen powers; and M. Piette has gone so far as to conclude, from the appearance presented by the ornamentation on one of these "amulets," which may possibly have been meant to represent the sun, that the artistic folk of the Pyrenees worshipped that body. Whether these surmises are true or not future explorations may perhaps decide; but it is obvious that the simple facts admit at present of other and less elaborate explanations.

Palæolithic man was unquestionably a true troglodyte, the caves which he is known to have inhabited being very numerous. In these we frequently come upon the old blackened hearths, round which the people gathered to cook and eat their meals; and the abundance of bones, split as only man could split them, testifies to the liking of the ancient savages for savoury marrow. No doubt, however, they did not live continually in caves, but in following the chase must often have camped out in the open field. And now and again such old camping-places have been detected, buried underneath more or less thick accumulations of flood-loam and sand. It is highly probable also that Palæolithic man may have constructed rude huts or tents when caves were not within reach, and on some occasions he may even have occupied temporary snow-houses, like those made by the Eskimo. We can hardly doubt that the character of his dwellings would be determined to a large extent by the nature of the climate. If this were mild and genial he may have wandered about during the greater part of the year in the pursuit of game—sheltering at night and during storms under trees or hastily improvised coverings of branches and rushes; while for the winter season he may have retired to some more permanent abode—and for this purpose caves would be well suited. But if the climate were severe—the summer being short and the winter prolonged—then of course a permanent dwelling-place would be more necessary. And it is evident from various circumstances that the artistic tribes, at all events, occupied caves as regular places of abode all the year round, issuing from them on hunting expeditions, and returning to them to feast upon the spoils. In bad weather they probably stayed at home and occupied their time in the manufacture of implements, as we may infer from the frequent presence in the cave-accumulations of numerous flint flakes, cores, and chips, and imperfect or unfinished tools. But the artistic folk sometimes at least wandered far afield. This is shown by the drawings of seals and a large cetacean which have been discovered in certain Pyrenean caves, and by the presence in the same caves of sea-shells, some of which have come from the Atlantic coast and others from the Mediterranean. We may therefore be quite sure that the Palæolithic reindeer-hunters occasionally visited the sea-shore, or carried on a kind of traffic with coast-dwellers.

Of the people themselves we know comparatively little, for very few skulls and skeletons have been preserved. From this circumstance it has been supposed by some that Palæolithic man did not pay much respect to his dead—an inference which, whether true or the reverse, is certainly not entirely proved by the evidence. For, even if burial had been a common custom among the Palæolithic tribes, so many changes have taken place since their disappearance—the surface of the ground has been so greatly remodelled by the action of frost, rain, and running-water—that we could hardly expect now to meet with any trace of their remains, or the graves in which these may have been laid. The only places where bones or complete skeletons are likely to have been occasionally preserved are caves and lake- and river-deposits. But caves, as we have seen, were in request as dwelling-places, and it is only such as were unfitted for this purpose that would possibly be used for interments. Again, as man would naturally be more wary than the animals by which he was surrounded, he would only at rare intervals be drowned in lakes and rivers, or fall a victim to inundations. Considerations such as these should lessen our surprise that remains of Palæolithic man are not more frequently encountered.

Isolated bones, and now and again skulls, and skeletons more or less complete, have been met with in a number of caves. Among the most famous of the crania is that found by Dr. Fuhlrott in a limestone-cave in the Neanderthal, near Hochdal, between Düsseldorf and Elberfeld, and the Engis cranium, discovered by Dr. Schmerling in a cave near Liège, where it was associated with bones of the cave-bear. Some French caves have more recently furnished similar remains. Of these the best known example is that of the rock-shelter of Cro-Magnon, in the valley of the Vézère, in which were found the bones of three men, a woman, and a child, described by MM. Broca and Pruner Bey. The complete skeleton of a man was likewise obtained by M. Rivière in a cave near Mentone, and M. Massénat made a similar discovery at Laugerie-Basse. MM. Lartet and Chaplain-Duparc also record the occurrence of a human skull along with Palæolithic implements in the Cave of Duruthy, near Sorde, in the Western Pyrenees. In several of the Pyrenean caves, as in that of Gourdan, human bones of Palæolithic age appear to have been not infrequently met with. Some of these were probably interred, others from their broken condition, and the marks upon them of blows and cuts or stabs, doubtless tell of violent death. Thus in the cave of Gourdan, M. Piette discovered several fragmentary skulls which bore evident indications of such treatment, and he infers that they are probably the remains of men slain in fight, whose heads were cut off and brought to the cave, where the brains may have been taken out and mixed in some kind of pottage, as is the custom of certain modern savages. But there is no evidence to show that Palæolithic man was a true cannibal. Amongst the enormous quantities of bones of various animals which occur in the cave-deposits, and which have been split to extract the marrow, those of man are never found in that condition, a strong proof that human flesh formed no part of a Palæolithic repast.

In fluviatile and lacustrine alluvia remains of Palæolithic man are of much rarer occurrence than in caves. They have been recorded, however, by various observers from the ancient löss or flood-loam of the Meuse and the Rhine. Professor Crahay of Louvain, so far back as 1823, described a human lower jaw which was dug up along with abundant remains of mammoths during the process of excavating a canal between Maestricht and Hocht. The jaw occurred underneath a depth of nineteen feet of ancient river-accumulations. M. Ami Boué, in the same year, disinterred human bones from the undisturbed flood-loam of the Rhine at Lahr, and the same deposit at Eguisheim, near Colmar, has yielded to the researches of Dr. Faudel a notable cranium, which was found at a depth of eight or nine feet. A human skull was got in flood-loam of the same age at Mannersdorf, and similar discoveries of human remains have been made at Clichy, in the valley of the Seine, and at Grenelle, in the valley of the Somme. Again, Professor Cocchi mentions that at Olmo, near Arezzo, in the valley of the Arno, a cranium was obtained, at a depth of nearly fifty feet, in lacustrine marl, and the tusk of an extinct species of elephant (*Elephas meridionalis*) occurred a few feet higher up in the same deposits.

Various and contradictory views have been held by anthropologists as to the character of the type or types of Palæolithic man, but, according to the recent researches of MM. de Quatrefages and Hamy, two dolichocephalic (long-headed) races occupied Europe during the Old Stone Period. Of these the earliest to appear was what they term the "Canstadt race," which is represented by crania found in the Neanderthal, the Val d'Arno, the Pyrenees, etc. This race was characterised by the more or less extraordinary prominence of the superciliary ridges, and by a low, narrow, and receding forehead. The orbits were very large and almost circular, the nasal bones were prominent, and the nasal orifices wide, while the upper jaw projected and the chin retreated. "In short," says M. de Quatrefages, "the face and cranium of the Canstadt man must, as a rule, have presented a strangely savage aspect. The body appears to have harmonised with the head. The few bones of the limbs, preserved more or less intact, indicate a stature of only 1 m. 68 to 1 m. 72 (5 feet 6 inches to 5 feet 8 inches), yet their proportions are athletic." The second race is called by the same anthropologist the "Cro-Magnon race"—the skull of the old man found in the rock-shelter at that place being taken as the type. This race was marked by its finely-proportioned skull, which is distinguished from that of the Canstadt type by its large and prominent forehead, and well-arched cranial vault, and by the absence of strongly-marked superciliary ridges. The upper part of the face was very broad in proportion to the lower, the nose projected boldly forward, as did also the upper jaw, and the slightly-triangular chin. The race was tall, and the bones indicate remarkable strength and muscularity. M. Hamy gives 5 feet 10 inches as the mean height. The Cro-Magnon woman measured 5 feet 5·3 inches, the old man of the same place 5 feet 11·6 inches, while the Mentone man was as much as 6 feet 0·8 inches. It is to this race that the artistic hunters of Périgord and the Pyrenees belonged.

I have incidentally referred to the fact that Palæolithic man was contemporaneous with the mammoth and other extinct or migrated species. The fauna of the Old Stone Period differed, as we shall see by and by, very much from that of the succeeding Neolithic Age. Among the animals were lion, hyæna, elephant, hippopotamus, rhinoceros, mammoth, bear, musk-sheep, glutton, reindeer, urus, and others, which are either locally or wholly extinct. The Neolithic fauna, on the other hand, comprised a group of animals essentially the same as that which now occupies Europe. Thus, the Palæolithic is marked off, as it were, from the Neolithic Period not only by the very distinct character of its human relics, but also by the strong dissimilarity of its mammalian remains. We can trace a gradual passage from Neolithic times into the succeeding Bronze Age, but no such transition has yet been detected between the relics of the New and the Old Stone Periods. The implements of the two periods in question are sharply contrasted. Even in the rare instances where the forms of the implements are analogous, a practised observer will readily detect a difference in the workmanship. In the exceptional cases referred to, "the difference is such," as Dr. Evans remarks, "that though possibly a single specimen [of Neolithic age] might pass muster as of Palæolithic form, yet a group of three or four at once strikes an experienced eye as presenting other characteristics." The implements of the one period are never found commingled with those of the other, nor do the characteristic faunas of the two ages ever occur together in one and the same undisturbed deposit. This remarkable circumstance must be kept in view when we are speculating on the lapse of time that separates the Neolithic from the Palæolithic Age. It will be my endeavour in the sequel to point out what seems to me to have been the cause of that gap or hiatus, but before doing so there are many other lines of evidence which I have yet to indicate; among these, not the least important is the question of climate. It is evident, indeed, that until we ascertain what kind of climate characterised the Palæolithic Period, we can form but a vague idea of the conditions under which the men of Canstadt and Cro-Magnon lived. In the two following chapters, therefore, I propose to discuss this question, taking for my data the mammalia and the land plants and mollusca which are found in those Pleistocene deposits to which Palæolithic man likewise belongs.

CHAPTER III.

CLIMATE OF PLEISTOCENE PERIOD—TESTIMONY OF MAMMALIA.

Geographical distribution of Mammals — Southern, Northern, and Temperate Group—Evidence of Mammalia as to Climate—Present climatic conditions in Europe, Northern Asia, and boreal regions of North America—Region of Tundras and Barrens—Arctic Forest Zone—Annual Migrations in Siberia—Similar Migrations cannot take place in Europe — Influence of the Gulf Stream on European Climate—Probable effect of its withdrawal—Alternations of Climate during Palæolithic Period.

Among the most remarkable animals which are now well known to have been contemporaneous with Palæolithic man in Europe are the lion, the hyæna, the serval, the Caffer cat, the hippopotamus, the rhinoceros, the elephant, the mammoth, the woolly rhinoceros, the musk-sheep, and others. Besides these there were many species which still inhabit our Continent, but their range at present is greatly restricted as compared with what it was in the Old Stone Age. It is this latter circumstance, indeed, that forms one of the most remarkable characteristics of the mammalian fauna of Palæolithic times. We cannot doubt that the climatic conditions which permitted such a fauna to roam over Europe must have differed very much from those of our own day. And this will appear indisputable after we have taken a glance at the present geographical distribution of some of the more prominent species. The ossiferous remains occur in such abundance and in so good a state of preservation that osteologists have had no great difficulty in recognising those of a number of animals which still survive in extra-European regions; and it is of the utmost importance, therefore, that we should consider the present range of such species, as there can be no question that this will throw considerable light upon our inquiry.

The LION (*Felis leo*).—This carnivore is at present confined to Africa and the south-west of Asia. Its range in Africa appears to have been within recent times co-extensive with that continent, but it has now disappeared from a large part of Egypt and the Mediterranean coast, and from the Cape of Good Hope, and the Gaboon and Niger districts. It even lived in Europe within historical times, for it is stated by Aristotle that the lions of Thessaly attacked the camels attached to the army of Xerxes. The maneless lion of Asia, which is only a variety of the African species, has also been considerably restricted in its range within recent years. It occurred at one time over wide areas in Central, West, and North-west India, but is now confined in Hindostan to the peninsula of Guzerat. It still lives in Asia Minor, and in Persia, along the borders of the Persian Gulf, it is common. The Cave-lion (*Felis spelæa*) of the Palæolithic Period was of somewhat larger dimensions than the living African species (*F. leo*), and was at one time believed to be a tiger. It had a very wide range in Europe, its remains occurring in many of the bone-caves of Sicily, Spain, France, Germany, Switzerland, Belgium, and England.

The SABRE-TOOTHED TIGER or LION (*Machairodus latidens*).—This is an extinct species, belonging to a distinctly southern type, which has been met with very sparingly in deposits of the Palæolithic Period. It occurs in what is called the Pliocene formation,[1] where it is associated with a number of species that indicate genial climatic conditions, from which it may be inferred that the climate of England was probably of this character at the time it lived in England.

The CAFFER CAT (*Felis caffra*) is met with in Egypt and West and South Africa. In Palæolithic times it was distributed over a wide area in Europe, extending from the borders of the Mediterranean north as far as England.

The LEOPARD (*F. pardus*) had a similar wide range in

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[1] See Table of Sedimentary Formations, Appendix A.

Palæolithic Europe; at the present day it ranges over all Africa, and Southern Asia, Sumatra, and Borneo.

The SERVAL (*F. serval*) is a South African species which has been met with in some of the bone-caves of the Mediterranean coast, as at Gibraltar.

The HYÆNA.—There are two species of hyæna, the striped hyæna (*Hyæna striata*) and the spotted hyæna (*H. crocuta*). The former is distributed over a wide area in North Africa and South-western Asia, while the latter is restricted to South Africa. Both species have been recognised in the bone-caves of Europe—the remains of *H. crocuta* being especially abundant. The spotted hyæna of Palæolithic times (*H. spelæa*) was of larger size than its living representative. It ranged over a great part of Europe, from the Mediterranean up to Northern England.

The ELEPHANT.—Several species of elephant have been met with in deposits of Palæolithic age. The African elephant (*E. africanus*) has left its remains in Southern Europe, but no trace of it has yet been found north of the Pyrenees and the Alps. The remains of an extinct dwarf species (*E. melitensis*) occur in Malta, Sicily, and Candia. It averaged four and a half feet or so in height at the shoulder. Associated with this dwarf species there appears to have been a yet lesser pigmy elephant (*E. Falconeri*) as determined by Mr. Busk. The average height of this animal could not have exceeded two feet six inches to three feet. Remains of these pigmy species are very abundant in the caves and rock-crevices of Malta. Dr. Leith Adams believes that Malta had even a third species of elephant (*E. mnaidrensis*), the average height of which was about seven feet. An extinct species of large size (*E. antiquus*) is met with frequently in the bone-caves and ancient river-gravels of Europe. It had a very wide range—from the Mediterranean north as far as Yorkshire. It also lived in North Africa. Another extinct form was *E. meridionalis*, met with in the preglacial deposits of Norfolk, and Pleistocene alluvia in France and Italy. A most characteristic species of Palæolithic times was the mammoth (*E. primigenius*), now extinct, which had a most extensive range—its remains having been found in nearly every country of Europe. They have not been met with farther south, however, than Spain and Central Italy. As every one knows, entire carcasses of this enormous animal have been preserved so perfectly in the frozen earth of Northern Siberia that we are very well informed as to its nature. It was of great size, much exceeding the largest of its modern representatives, and was provided with a covering of long black hair, mixed at the roots with a thick fleece of reddish wool.

The HIPPOPOTAMUS (*H. amphibius*) is confined to Africa, where its range has been considerably restricted within historical times, for it formerly abounded in the Delta of the Nile. It is common to most of the rivers in the south of the Continent, and is found in the Niger, the Senegal, and the Nile. A smaller species (*H. liberiensis*) occurs in the River St. Paul, in Liberia. The remains of a large species (*H. major*) which is believed to be identical with the African form (*H. amphibius*) have been found in ancient river-gravels and bone-caves in Europe as far north as Yorkshire. It is remarkable, also, that the bone-caves of Italy, Sicily, and Malta have yielded the remains of a small species of hippopotamus (*H. Pentlandi*) in great abundance.

The RHINOCEROS.—The living species of rhinoceros are southern forms, being distributed over Africa south of the Sahara, and over wide regions in India, Burmah, and Sumatra. No fewer than four species, all of them extinct, have left their remains in the Pleistocene alluvia and bone-caves of our continent. Of these the most common is the woolly rhinoceros (*R. tichorhinus*) a carcass of which was found many years ago (1771) in frozen ground on the banks of the Vilni, a branch of the Lena. This rhinoceros had a range probably as extensive as that of the mammoth, but hitherto its remains have not been met with south of the Alps and Pyrenees. Of the three remaining species, *R. hemitœchus* (*R. leptorhinus*, Owen) is the more common; it is found both in bone-caves and old river-gravels, and ranged north from the Mediterranean coast as far as Yorkshire. *R. megarhinus* is of much less frequent occurrence, but it ranged north from Southern Europe into England. *R. Merckii* (Jaeger and Kaup) occurs sparingly in Pleistocene deposits in Middle Europe. It is possible that two different species have been described under this name, M. Lartet having been of opinion that *R. Merckii* of De Meyer is the same as *R. etruscus,* Falc., a species found in the Upper Pliocene. Professor Brandt, again, thinks that *R. etruscus* is merely a variety of *R. Merckii,* Jaeg.

The BEAR.—Three species of bear lived in Europe in Palæolithic times, of which only one is now indigenous, namely the brown bear (*Ursus arctos*). The others were the grisly bear (*U. ferox*), now confined to the west half of North America, and the great cave-bear (*U. spelæus*), now extinct, which was nearly allied to the brown bear. All these had a considerable range in our continent—the remains of the cave-bear occurring in most of the bone-caves of England, and being common also in those of Central Europe, while those of the grisly bear are met with in England, Belgium, Germany, and even as far south as Gibraltar and Sicily. The brown bear was also a common form in Central Europe, and its remains occur even in the caves of Palermo.

The MUSK-SHEEP (*Ovibos moschatus*) is a characteristic Arctic species, being restricted to Melville Island, Greenland, and the adjacent regions in North America. Formerly, however, it ranged into England, Belgium, Germany, and Southern France.

The REINDEER (*Cervus tarandus*) ranges over a vast region in North America, Northern Europe, and Siberia, its southern limits corresponding very nearly to the isothermal line of 32°. It is gradually being driven north in Europe before the advance of civilisation, and there are some slight grounds for believing that it lived in the extreme north of Scotland down to early historical times. Its remains occur abundantly in Palæolithic deposits over a large part of Europe, even as far south as Aquitaine in France.

The WOLVERENE or GLUTTON (*Gulo borealis*) inhabits all the northern parts of both hemispheres. It spread south in Palæolithic times to the shores of the Mediterranean (Mentone).

The ARCTIC FOX (*Canis lagopus*) which, as its name implies, is a truly boreal species, occupying the higher latitudes of Europe, Siberia, and North America, has been widely met with in Palæolithic deposits, and appears to have had a range hardly less extensive than that of the glutton.

The COMMON MARMOT (*Arctomys marmotta*) and the POUCHED MARMOT (*Spermophilus citillus*) have a very wide range at the present day, stretching from Central Europe through Siberia to North America. They are generally found in mountainous districts, and often at lofty elevations, where the climate is necessarily severe. The pouched marmot lived in the low grounds of Europe as far south as Southern France in Palæolithic times, and its remains have been detected in English and Belgian caves, in the latter of which the common marmot also occurs. Remains of the marmot have also been got at Mentone and in the low grounds of Piedmont at the foot of the Moncalieri-Valenza hills.

The LEMMING.—Three species of lemming have been recorded from Palæolithic deposits, namely *Myodes lemmus*, Pall., the common or Norwegian lemming, *M. torquatus*, Pall., the torquated lemming, and *M. obensis*, the Siberian lemming. The first is a native of Russian Lapland, Norway and Sweden; the second occurs in circumpolar regions—in Siberia, North America, and Greenland; while the last-named is met with in Siberia and Arctic North America. In Palæolithic times lemmings ranged south to Bohemia, Saxony, Upper Franconia, and Central France.

The TAILLESS HARE or PIKA (*Lagomys pusillus*) is another living boreal species the remains of which are met with in bone-caves in England and Belgium. The form *L. corsicanus* occurs in breccia in Corsica, and *L. sardus* in cave-deposits in Sardinia.

The IBEX (*Capra ibex*) is found living in the Alps, and another species (*C. pyrenaicus*) inhabits the Pyrenees; an ibex is also met with in the mountains of Andalusia. The ibex lived plentifully in the region of the Jura, the south of France, and Northern Italy, in Palæolithic times. Great quantities of the bones of this animal also occur in the Gibraltar caves.

The SNOWY VOLE (*Arvicola nivalis*), now a native of the higher Alps, formerly lived in the low grounds of Lombardy.

The Chamois (*Antilocapra rupicapra*) is another species which is now restricted to the Alps and the Pyrenees. Its remains are met with in the bone-caves of Belgium and the south of France.

Among other animals of the Palæolithic Period in Europe were the Lynx, the Wild-cat, and other living carnivores, and the Aurochs or Lithuanian Bison, the Urus, the Great Irish Deer, the Saiga, the Stag, the Roe, and so forth. Of these the Great Irish Deer, now extinct, was formerly widely distributed over Middle Europe, and survived the Palæolithic Period. It is even supposed by some writers to be referred to in the Niebelungen Lied as the "fierce schelch." There can be little doubt that it lived under climatic conditions similar to those that characterise the temperate latitudes of Western Europe. The Aurochs or Lithuanian Bison is preserved by the Czar in one of the forests of Lithuania, otherwise it is no longer feral in Europe. It still lives, however, in the Caucasus. The Urus appears to be represented solely by the white cattle of Chillingham and Hamilton, but it exceeded these considerably in size. Among other species of Pleistocene times whose presence indicates a temperate climate are Otter, Beaver, Hare, Rabbit, Marten-cat, Stoat, Weasel, Wolf, Fox, Horse, and others, some of which have been already mentioned.

Before we proceed to the discussion of the climatic and geographical conditions of Europe during the Old Stone Age, it may be well to summarise the results of our inquiries into the present geographical distribution of those species which are recognised as still living. We find, then, that the animals which were contemporaneous in our continent with Palæolithic man, may be grouped as follow:—

1. Southern Group,[1] comprising those species that are now found living in latitudes south of the Black Sea and the Mediterranean:—

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[1] To this group Professor Dawkins adds the porcupine, remains of which have been met with in the caves of Belgium. It is now a native of Southern Europe, but ranges south into Africa.

Hippopotamus.
African Elephant.
Spotted Hyæna.
Striped Hyæna.
Serval.
Caffer Cat.
Lion.
Leopard.[1]

2. Northern and Alpine Group, comprising those species which are now met with only in northern latitudes, or in mountain-ranges where similar climatic conditions obtain :—

Musk-sheep.
Glutton.
Reindeer.
Arctic Fox.
Lemming.
Tailless Hare.
Alpine Hare.
Marmot.
Spermophile.
Ibex.
Snowy Vole.
Chamois.

3. Temperate Group, comprising species which are characteristic of temperate latitudes :—

Urus.
Bison.
Horse.
Stag.
Roe.
Saiga.
Beaver.
Hare.
Rabbit.
Otter.
Stoat.
Weasel.
Marten.
Wild-cat.
Fox.
Wolf.
Wild-boar.
Brown Bear.
Grisly Bear.

Of the extinct species of elephant, we may reasonably infer that *E. meridionalis, E. melitensis, E. Falconeri, E. mnaidrensis,* and *E. antiquus,* belonged to the southern group of animals, while the hairy mammoth may be set down in the northern group, although it is highly probable that it ranged far into the territories occupied by the temperate group. The woolly rhinoceros is so frequently found in conjunction with the mammoth, that we must regard it also as being essentially a north-temperate species. The other three species of rhinoceros

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[1] For fuller details than I have been able to give, the reader is referred to Boyd Dawkins's *Cave-hunting* and *Early Man in Britain.*

(*R. megarhinus*, *R. Merckii*, and *R. hemitœchus*) were no doubt members of the southern group, as also were the sabre-toothed tiger (*Machairodus latidens*) and the dwarf hippopotamus (*H. Pentlandi*). The Irish deer was most probably a temperate species, and the cave-bear is with some reason also relegated to the temperate group. Thus of these extinct species, not less than ten belonged to types whose nearest analogues at the present day must be sought for in southern regions.

The animals that were contemporaneous with man in the Old Stone Age, form, as we have seen, a somewhat motley assemblage, comprising representatives from many widely separated zones. Arctic and boreal are strangely commingled with temperate and southern species, and we may search the whole living world in vain for any similar concourse of groups so discordant and unlike. If we confine our attention to the forms with which we are most familiar, we should say that they betokened climatic conditions not unlike those of our own and similar latitudes. But then we are confronted by the northern species, such as musk-sheep and reindeer, which in Palæolithic times were distributed over all Northern and Middle Europe as far south at least as Southern France. Now it is quite impossible that these animals could have ranged to this low latitude unless the climate of prehistoric Europe had differed greatly from the conditions that now obtain. How could the climate of France have been other than cold and ungenial when the reindeer and the musk-sheep were hunted by Palæolithic man in the low grounds of Aquitaine? We are reminded, however, that during the same Old Stone Age, the hippopotamus and its southern congeners visited England and North-western Europe; from which we are surely to infer that those regions then experienced a mild and genial climate. Thus the evidence of one group seems to contradict that of the other. The contradiction, however, is only apparent.

Europe, owing to its geographical position, enjoys what may be termed an insular climate. It is bathed along the whole western coast-line by the waters of the wide-stretching Atlantic, the mild and moist winds from which modify alike the heat of summer and the cold of winter. And this of course is more especially the case with the countries of Western and North-western Europe. As we recede from the Atlantic coast-line, and pass inland along the same parallel of latitude to the central and eastern regions, we find that the difference between the seasons becomes more and more strongly marked, until when we cross into Asia we meet with the greatest contrast between summer and winter. The extremes of temperature experienced in Europe on the same or nearly the same parallel of latitude, are well shown by comparing the summer and winter temperatures of the following places :—

	Lat. N.	Longit.	Temp. in January.	Temp. in July.	Difference between Winter and Summer.
Westport .	53° 48′	9° 29′ W.	43°·9 Fahr.	58°·1 Fahr.	14°·2
Liverpool .	53 24	2 59	39·8 ,,	61·5 ,,	21·7
Bremen .	53 5	8 49 E.	29·5 ,,	64·6 ,,	35·1
Stettin .	53 27	14 32	28·2 ,,	64·2 ,,	36·
Bromberg .	53 9	18 2	26·15 ,,	65·3 ,,	39·15
Svislotch .	53 20	28 56	22·5 ,,	64·8 ,,	42·3
Zamartin .	53	39 30	11·8 ,,	66·2 ,,	54·4
Penza . .	53 15	44 57	7·3 ,,	68· ,,	60·7

In Northern Asia and the corresponding latitudes of North America, we encounter ranges of temperature which are greatly in excess of those that are experienced in Northern Europe. Thus at Jakutsk the mean temperature of July is + 62°·8, while that of January sinks to −40°·4, a difference of as much as 103°·2 ; yet Jakutsk is in nearly the same latitude as Aalesund in Norway, where the July temperature only reaches + 54°·5, and that of January does not fall below + 28°·8, a difference of 24°·7. Again, at Fort Confidence on the shores of Great Bear Lake, the mean temperature of summer (June, July, and August), is + 48°·2, and that of winter (December, January, and February) −22°·9—a difference of 71°·1, or taking the July and January temperatures, we have for the former + 52°·9, and for the latter −26°·7, giving a range of 79°·6. Now Fort Confidence is in nearly the same latitude as Bodö in Norway, where the temperature of July is + 54°·5, and that of January + 26°·6, a difference of only 27°·9. This greater range of temperature in Northern Asia and North America naturally affects to a very considerable degree the vegetable and animal products. Thus, as every one knows, there are vast tracts in those regions which are subject to a climate that forbids the growth of trees. In these wide "barren grounds" mosses and lichens form the prevailing vegetation, and next to these come grasses, sedges, and rushes, and dwarf willows. This treeless zone presents a very irregular margin towards the south. Thus in North America it descends to Labrador in latitude 57°, from which, as we follow it across that continent, it gradually rises to higher and higher latitudes until it reaches the delta of the Mackenzie River in 69° N. lat. After leaving the Mackenzie, it trends more towards the south, and terminates on the shores of Behring Strait in 65° N. lat. On the opposite or Asiatic coast, the boundary line between the tundras or barrens and the region of trees begins in 63° N. lat., and sweeps away in a north-westerly direction till it reaches the Lena in 71° N. lat., after which it again extends more to the south and crosses the Obi a little beyond the Arctic Circle. It now sweeps farther and farther to the north as it traverses Europe, so that only a narrow fringe of "treeless ground" appears in Lapland and the north of Russia.

Immediately south of the "barrens" of North America and the "tundras" of Siberia comes the belt of Arctic forests, which are composed almost exclusively of coniferous trees. These forests cover an immense territory, and extend with hardly any interruption across the three northern continents, forming a zone which is 15° to 20° in breadth. The limits of arboreal vegetation are of course determined by climatic conditions, the area to the north being swept in winter by cold winds coming from the ice-laden Arctic seas, before the breath of which every green thing shrivels up. Vast areas of the barren grounds during that season are covered with thick snow—lake and river and morass are frozen—and hardly a trace of animal life is to be seen. But soon after the return of spring, when the ground begins to thaw and the snow to vanish, lichens and herbs and grasses reappear, and the summer heat by and by becomes almost as intolerable as the winter cold. The tundras are now enlivened by the presence of great herds of reindeer and other animals, and by vast flights of wild birds which find a plentiful harvest of food in the waters of river and lake and sea.

Thus, owing to the strongly-contrasted conditions of summer and winter in these Arctic regions, both birds and beasts are compelled to perform great migrations. In winter the reindeer seek the shelter of the woods, where they trespass upon the territory of the elk or moose-deer, and in which they frequently fall a prey to wolves and bears. As soon, however, as the milder weather begins, they return in large bands to the tundras and barrens, feeding on the lichens that are softened by the melting snow.

The area over which the reindeer-migrations take place is vastly more extensive in America and Asia than in Europe, its southern limits corresponding very nearly to the isothermal of 32°. No doubt this area extended farther south in Norway within recent years; but even were the disturbing influence of man to be entirely withdrawn, we cannot believe that under present climatic conditions the reindeer would ever reach in Western Europe the same low latitudes that it now attains in Asia and America, for it ranges into Kamtschatka as far south as the parallel of 50° N. lat., which it will be remembered passes through the north of France.

The climatic conditions that induce great migrations, like those of the northern regions of Asia and North America, do not obtain in the corresponding territories of North-western Europe. Our prevalent winds are westerly and south-westerly, and come to us laden with the warmth and moisture of the Gulf Stream, and thus, as I have said, we enjoy a kind of insular climate, with no great extremes of heat and cold. Such being the case, and it being perfectly well ascertained that during

Palæolithic times the European coast extended only a little distance farther into the Atlantic, we may well ask how the presence of the reindeer in the south of France and the hippopotamus in the north of England can be accounted for. Owing to their geographical position, the north-western regions of our continent could not possibly have been subjected to a climate at all comparable with that of Siberia. The influence of the neighbouring Atlantic would effectually prevent the occurrence of strongly-contrasted seasons. We may therefore at once dismiss the hypothesis of great annual migrations which some writers have advanced to account for the startling association in Palæolithic deposits of such discordant species as reindeer and hippopotamuses, musk-sheep and elephants. The fauna of Palæolithic times comprised, as we have seen, not only northern and temperate forms, but a well-marked group of southern animals. According to the migration-hypothesis, therefore, we are to suppose that in summer huge pachyderms like the elephant and hippopotamus migrated from the south of Europe as far north as England, and that on the approach of winter they returned to their "head-quarters," and were followed by the reindeer and its congeners as far as the foot of the Alps and the Pyrenees. Such a supposition, however, is manifestly unreasonable, inasmuch as it is opposed to all that we know of the habits of hippopotamuses, elephants, and rhinoceroses; and the same might be said of several other species that belong to the southern group of Palæolithic times. How impossible, indeed, does it seem that those unwieldy pachyderms could in one year traverse the whole breadth of Europe, so as to trespass on the territory of the reindeer and the musk-sheep, and then retreat with sufficient rapidity to escape the severity of a winter before which the arctic mammals were forced to flee to the south of France.

The anomalous commingling of northern, southern, and temperate forms points, not to one prolonged period characterised by extreme summers and winters, but to changes of climate very gradually effected through a long course of time. We may be quite sure that when arctic and alpine animals were living in the low grounds of France, the climate of all Europe, especially the middle and northern regions, was cold and ungenial, and that when hippopotamuses frequented the rivers of England, very different climatic conditions prevailed. Let us try and realise what those varying climatic conditions may have been.

We have seen that the southern species are now restricted to regions where, as a rule, the yearly temperature is considerably in excess of that now experienced even in the south of Europe. We have no reason to suppose, however, that such a high temperature is absolutely necessary to their existence. Could we but get rid of the inclement winters of the north, so that no chilling frosts should affect the vegetation, it is evident that the Arctic forests would gradually invade and spread over the barrens and tundras. The north-temperate and temperate regions would also support a more abundant growth, and wide areas which are now incapable of cultivation, either by reason of their elevation or their high latitude, might readily be made to yield good harvests. It is quite possible, indeed, that Scotland might, under certain conditions, acquire a winter temperature approximating to that of the south-west of France. A change like this might be brought about without any revolution in the geographical position of our continent. Were the ocean currents that even now so greatly modify our winters to be very largely increased in volume, they would of course raise the general temperature of the Atlantic and Northern Oceans to a still higher degree, and so would effect a corresponding amelioration of the climate of the neighbouring lands over which the westerly winds distribute their warmth and moisture. There are many good grounds for believing that considerable changes in the volume of warm ocean currents have occurred in the past; and as, owing to various causes, such currents may be made to flow with a greatly increased breadth and depth, so, on the other hand, they may be reduced, and even turned out of their course and forced to go in some other direction. But no changes in the direction or the volume of ocean currents in the North Atlantic could ever give rise to a Siberian climate in North-western Europe. Were the Gulf Stream, which so profoundly modifies the winter temperature of Europe, to be withdrawn, the winters in our islands would become colder than they are at present by more than 25°.[1] Nor would this fall of temperature be counterbalanced, as it were, by a corresponding increase of temperature in summer. On the contrary, we might look for quite an opposite result. Superficial currents of cold water coming from the Arctic regions would cool the summer temperature along all the west coast of Europe, just in the same way as the Labrador Current affects the summer temperature of the coast lands of British America and the New England States. A glance at the following Table, in which are given the mean winter and summer temperatures of places in the same latitudes of North America and Europe, will show what effect the Gulf Stream has in modifying our European climate. Were that current to disappear, our coasts might well be washed by as cold water as that of the Labrador Current; and thus not only the winter, but the summer also, over all Western and North-western Europe would be considerably affected.

East Coast of N. America.	N. Lat.	Mean Temp. of January.	Mean Temp. of July.	West Coast of Europe.	N. Lat.	Mean Temp. of January.	Mean Temp. of July.
Lichtenau .	60° 30′	+22°·5	+46°·4	Bergen . .	60° 23′	+32°·6	+53°·6
Hebron . .	58 16	-5·1	+46·1	Wick . .	58 25	+38·5	+56·5
Labrador Coast[2]	55	+5·	+49·	Killybegs .	54 38	+41·4	+58·7
				Newcastle .	54 58	+38·7	+58·1
				Königsberg	54 42	+24·2	+62·8
St. John .	47 27	+23·5	+56·	Nantes . .	47 13	+41·2	+71·1
Halifax . .	44 39	+22·6	+63·5	Bordeaux .	44 50	+41·	+69·1

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[1] The normal temperature of the latitude of London is 40°, which is 30° higher than it would be were all oceanic and aerial currents to be stopped. And Dr. Croll calculates that the actual rise of temperature at London due to the influence of the Gulf Stream, over and above all the lowering effects produced by Arctic currents, is as much as 40°.—See *Climate and Time*, p. 43.

[2] The winter temperature is that of the January isothermal line, which reaches the Labrador coast in lat. 55°. The July isotherm of 50° passes through lat. 53° 30′, the July temperature of 49° given above being only approximate. The temperature for that month at Nain on the same coast, in lat. 56° 22′, is 48°·2 ; and the mean of January is 2°·4.

With a mild and genial winter prevailing as far north as Scotland and Norway, it is evident that the present distribution of flora and fauna would be very considerably affected. We might well have characteristic temperate forms, such as the stag, oxen, bisons, horses, and others living all the year round in Lapland, and even in the country of the Samoyedes, while the northern species were restricted to the lofty mountain-tracts, or banished out of Europe altogether. The climate of England and France under such conditions as we have supposed would support a vigorous vegetation, and might readily be occupied by many animals that are now restricted to more southern latitudes. There is really nothing in the habits or mode of life of the hippopotamus, for example, that would lead us to suppose that for it a tropical climate is indispensable. A country that furnished plenty of succulent plants, and whose winters were sufficiently genial to keep the streams and lakes and rivers free from ice, might very well suit the hippopotamus and not a few of his present associates. Indeed, one might almost infer from the great size attained by many of the southern forms during the Old Stone Age that these animals throve better under the temperate climate of Europe than they do now in the warm regions of Africa. The large size of many of the temperate species—the cervine, bovine, and other animals that were contemporaneous in our continent with the great pachyderms, and whose dwarfed descendants still live in these latitudes—is also remarkable. Many causes, certainly, may have combined to bring about this change in the size of these animals. They have all experienced more or less of a hard struggle for existence, and their feeding-grounds have been greatly limited since the time when they were hunted by Palæolithic man. It is doubtful, however, whether the diminished size of the pachyderms and their associates can be entirely accounted for in this way, and whether it may not be due in part to the less favourable climatic conditions under which they now live.

It was certainly not under tropical conditions that the old pachyderms occupied our continent. The climate of all North-western Europe at that time must have been essentially temperate, so that what we now call our temperate fauna ranged then from the shores of the Northern Ocean down to and even south of the Pyrenees and the Alps. Carnivorous animals like the lion, the hyæna, and the leopard, would be also widely distributed, finding abundant food in nearly every part of the Continent. Thus at the time hippopotamuses wallowed in the rivers of France and England, and great herds of cervine and bovine animals wandered from glade to glade, our caves and forests were haunted by fierce carnivores. The reindeer and its associates could not flourish under such climatic conditions, and their range in Europe must therefore have been extremely limited. Marmots and lemmings would retire to the alpine heights, and reindeer might possibly linger upon the lofty plateaux of Northern Scandinavia. It is more probable, however, that they lived beyond the precincts of Europe, and may have occupied territories that are now drowned in the icy waters of the Northern Ocean. For we know very well that Europe and Asia within a recent geological period have extended much farther into the Polar Seas, and that a wide stretch of Arctic land, of which Novaia Zemlia and Spitzbergen formed a part, has been recently submerged.

We have now only to suppose that, after enduring for some prolonged period, such climatic conditions gradually changed. The warm ocean currents became more and more reduced in volume, and the winters in consequence waxed colder and colder. Such a change might have taken place at so slow a rate that generations might have come and gone before any decided difference in the climate could have been recognised. But as the winter cold increased, both flora and fauna would begin to testify to the change—the hippopotamus, and doubtless other animals, gradually disappearing from Britain and Middle Europe. Many of the hardier temperate forms, however, would continue for a time to tenant the lands which the bulky pachyderms had vacated. But when the winters had become so intense as to favour the existence of reindeer and musk-sheep in the south of France, we may well believe that the major portion of Middle and Northern Europe would be a dreary desert waste. The temperate fauna would be living in the southern districts of our continent and North Africa, but it is very doubtful whether the hippopotamus would be able to endure the winter cold which must then have characterised the shores of the Mediterranean.

We have seen that archæologists have good reasons for thinking that the men who lived in the south of France in the latest stage of the Palæolithic Period were associated with the reindeer and the mammoth. The fact that the climate was then cold and ungenial is curiously illustrated by the circumstance pointed out by the late Mr. Christy that heaps of bones and other garbage could be safely left by the Palæolithic hunters to accumulate on the floors of the caves where they lived. Had the climate been other than frigid it is not likely that this would have been the case, for under a mild temperature such refuse-heaps would putrefy, and their exhalations become unbearable. Nor are the reindeer and the mammoth the only animals whose presence testifies to the former rigour of the climate in the south of France and North-western Europe. Small animals, such as marmots, lemmings, and tailless hares, occupied at the same time the low grounds of England, Belgium, and France; and whatever we may think of the evidence yielded by the reindeer, we cannot but admit that the presence of the smaller animals points to a settled occupation of the land that endured for a prolonged period. Even if we conceded the possibility of the reindeer having migrated from Norway and the Highlands of Scotland down to the south of France in one season, we should still be unable to allow that marmots and pikas could have performed the same annual journey. The lemmings of the Old Stone Age doubtless lived very much in the same way as their descendants in Lapland do at the present day, namely on roots, grass, the shoots of dwarf willow and birch, and largely on lichens, for which they burrow in winter time under the snow. They, with their congeners the marmots, tailless hares, arctic foxes, musk-sheep, gluttons, and other alpine and northern species, were settled inhabitants of those low grounds of Europe that are now occupied only by the temperate group. It does not by any means follow, however, that the arctic or northern group of animals was distributed over all Europe, from the extreme north down to France, at one and the same time. The cold climatic conditions that forced them from their head-quarters must have come on gradually, pushing them slowly farther and farther to the south; so that when at last they came to occupy the low grounds of France and the south of England, it may well have been that the regions farther north were too inhospitable even for them. Indeed, we can hardly escape from this conclusion when we bear in view the geographical position of North-western Europe. But to this point we shall return after we have considered certain geological evidence which will come before our attention in the sequel.

CHAPTER IV.

CLIMATE OF PLEISTOCENE PERIOD, *continued*—TESTIMONY OF PLANTS AND MOLLUSCS.

Preservation of land-plants exceptional—Plants in the Travertine of Massa Marittima in Tuscany—Plants in tufas of Provence; in tufas of Montpellier, etc.; in tufa of La Celle near Paris—Views of Count Saporta—Plants in tufa of Canstadt—Pleistocene lignite of Jarville near Nancy; its plant and insect remains—Mr. Nathorst on Arctic flora in peat of Switzerland, Germany, etc.; M. Tournouër on shells in tufa of La Celle—M. Bourguignat on shells in "diluvium gris" of Paris—Shells in tufas of Canstadt; in English Pleistocene deposits—Dr. Sandberger on shells and mammalian remains in löss of Würzburg—M. Locard on shells in Corsican breccias—Summary of evidence.

THE conclusions to which we have been led by a study of the mammalian groups characteristic of the Pleistocene Period are strongly supported by the evidence derived from an examination of those plants and shells which from time to time have been discovered in freshwater accumulations belonging to the same age. Just as we found among the mammalia well-marked northern and southern species, together with many temperate forms, so we encounter amongst the groups of plants, and land- and freshwater-shells which we are about to examine, many species which could not possibly have lived side by side. Thus in Central Europe the Pleistocene deposits have in some places yielded arctic and northern plants, whilst in other places the flora they contain has a temperate or even a preponderating southern facies. And the same holds true of the mollusca. Let us glance for a little at some of the more interesting "finds" of land-plants, taking first in order those which appear to indicate mild and genial climatic conditions.

It is generally only under exceptional circumstances that land-plants are preserved; they occur far less frequently in a recognisable condition than the shells of molluscs and the hard parts of mammals. The fossiliferous Pleistocene deposits, as we shall learn in subsequent chapters, consist chiefly of river-gravels and loams, and of accumulations formed in caves and rock-fissures. But the river which carries along sand and gravel will as a rule sweep the *débris* of land-plants out to sea. The few plants which may now and then become embedded will often be macerated, rubbed, and water-worn, those tender parts upon which botanists chiefly rely for the determination of species being as a rule destroyed. Again, loose deposits of gravel and sand are not good preservers, for they allow water to soak through them more or less freely, and thus any plants they may contain will tend to decompose past recognition. Thus it is only now and then that plant-remains are found in the river-deposits of Pleistocene times, and these consist chiefly of water-worn sticks and logs. In cave-accumulations it is by the merest accident that plants could become preserved, and in point of fact almost the only traces that occur in such deposits consist of the more or less charred relics which mark the sites of ancient Palæolithic hearths. Occasionally, however, we come upon beds of vegetable matter buried under lacustrine accumulations, and from these much important evidence has been gathered. And not less noteworthy are those masses of calcareous tufa or travertine which have been formed upon the borders of incrustating springs and cascades, for they have frequently preserved leaves, seeds, fruits, and other remains of plants, together with quantities of shells. Among the most interesting of those tufa deposits are those of Lipari and Tuscany, described by M. Ch. Th. Gaudin;[1] those of Castelnau and other places, near Montpellier, examined by M. G. Planchon;[2] those of Provence, made known to us through the admirable researches of Count Saporta,[1] who, along with M. Tournouër, has recently given an interesting account of the fossiliferous travertine near Moret[2] (Seine-et-Marne). Another most important tufa is that of Canstadt in Würtemberg, the shells of which have been studied by Klein,[3] and the plants by Professor Heer.[4]

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[1] *Mem. de la Soc. Helv. des Sci. Nat.* t. xvii.; *Bull. de la Soc. Vaud. des Sci. Nat.*, t. vi. p. 459.

[2] *Bull. Soc. Bot. France*, t. iv. p. 582; *Etude sur les Tufs de Montpellier*, 1864.

The travertines of Massa Marittima in Tuscany have yielded a number of plant-remains, amongst which we find indigenous species commingled with forms, some of which, although still European, are not now natives of Tuscany, while others are exotic, and yet others are extinct. Amongst these last are several well-known Tertiary species, such as *Liquidambar europæum*, Al. Br., *Platanus aceroides*, Al. Br., *Planera Ungeri*, and *Betula prisca*, and some peculiar forms, as an arbor vitæ (*Thuja saviana*, Gaud.), allied to the living *T. occidentalis*, and a walnut (*Juglans paviæfolia*, Gaud.) One of the most noteworthy plants is the laurel of the Canary Islands (*Laurus canariensis*, Webb), a variety of the common laurel (*Laurus nobilis*). It does not now grow spontaneously in Italy, and until recently was believed to be an extra-European species. But Saporta describes it as growing wild on the banks of the Gapeau, near Toulon, on the French shores of the Mediterranean, where the orange is cultivated in the open air. Professor Marion has seen it in the gorges of Chiffa, near Blidah in Algeria, but its head-quarters are the Canary Islands, where it is found flourishing luxuriantly in the woody regions with a northern exposure, between a height of 1600 feet and 4800 feet above the sea—regions which are nearly always enveloped in steaming vapours, and exposed to the heavy rains of winter. Snow, which falls now and then in an extra rigorous season, melts even at the upper limits of the district in question almost as soon as it appears. The temperature indeed keeps above 69° F. during the greater part of the year, in the winter months (November, December, and January) rarely falling below 59° or 60°, and only on the coldest days reaching 49°. The common laurel and the beech are frequently found associated in the Tuscan tufas, showing that they formerly grew side by side in that region. This, however, is no longer the case; the laurel requires more shade than it could find under present conditions, while the beech has retired to the northern flanks of the Apennines to obtain the fresh cool climate which is now denied to it in the low grounds of Tuscany. In the same deposits occur also the elm, the white-beam (*Pyrus aria*), the gray willow (*Salix cinerea*), the ivy, etc. Other species are evergreen oak (*Quercus ilex*), pubescent oak (*Q. pubescens*, Wild.), Greek periploca (*Periploca græca*), laurustinus (*Viburnum tinus*), European nettle-tree (*Celtis australis*), fig-tree (*Ficus carica*), vine (*Vitis vinifera*), judas-tree (*Cercis siliquastrum*), manna-ash (*Fraxinus ornus*), sarsaparilla (*Smilax aspera*), and various maples which still characterise the flora of the Mediterranean region. The tufas of Lipari are marked by a similar assemblage of species, amongst which the common laurel and its variety (*Laurus canariensis*) are conspicuous; but the Tertiary and extinct forms mentioned above are wanting.

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[1] *Compt. Rend. de la 33e Session du Congrès Scientifique de France; Bull. Soc. Bot. France*, t. xiv. p. 179; *Annuaire de l'Inst. des Provinces*, t. xx. p. 9.

[2] Saporta: *Bull. Soc. Géol. France*, 3e Sér., t. ii. p. 439; *Compt. Rend. du Congrès Internat. d'Anthrop. et Archéol. Préh.*, 1874, p. 80; *Compt. Rend. Assoc. Franç. pour l'Avance. des Sci.* 1876, p. 640; Tournouër: *Bull. Soc. Géol. France*, 3e Sér., t. ii. p. 443; t. v. p. 646.

[3] *Jahreshefte des Vereins für vaterl. Naturk. in Württemberg*, Bd. ii. p. 60.

[4] *Die Urwelt der Schweiz*, 2te Aufl., p. 534.

According to Saporta they are absent also from the tufas of Provence—the flora of which corresponds in all other respects with that of the Italian deposits. Among the species enumerated by him are the Canary laurel, which is associated, as in the Italian tufas, with the common laurel, European nettle-tree, fig-tree, vine, laurustinus, judas-tree, oak, hazel, white poplar, various willows and elms, Montpellier maple, common maple (*Acer campestre*), clematis, ivy, dogwood, spindle-tree, and fustic, a group very nearly the same as that which flourishes at present within the same limits. But commingled with these species are others no longer natives of Provence, such as Salzmann's pine (*Pinus Salzmanni*, Dun.), the Pyrenean pine (*Pinus pyrenaica*, Lap.), and the dwarf or mountain-pine (*Pinus pumilio*), which have abandoned that region and sought refuge in the mountains, where they occupy limited areas often widely separated. Salzmann's pine grows naturally now only in the Forest of Saint Guilhem, in a mountain-gorge situated at the foot of the Cevennes, beyond the zone of olives, at a distance of about twenty-five miles from Montpellier, while the Pyrenean pine has retired to a valley in the Pyrenees. The dwarf pine occurs in the mountainous regions of Central Europe, where it is found occupying calcareous soils at an elevation of 1300 to 2500 mètres above the sea. It is a tree which prefers humid situations—growing in wet rocky ground, and even along the banks of streams in the bottoms of valleys.

It is further noteworthy that these species are associated in the tufas of Provence with the lime (*Tilia europæa*), a peculiar maple (*Acer opulifolium*), and raspberry (*Rubus idæus*), which, although still natives of Provence, are no longer really spontaneous upon the margins of streams in the low-lying parts of that region. It is only in forest-clad hilly districts, and chiefly in situations with a northern exposure, where they can obtain in Provence the requisite shade and coolness. Saporta further calls attention to the fact that the Aleppo pine and the olive—species which demand considerable summer heat rather than a humid climate, and are so characteristic of the Mediterranean region of to-day—are entirely wanting in the tufas. Even the evergreen oak is absent from the deposits of Provence, and is very rare in the tufas of Southern Europe. The presence of the vine and the fig-tree further shows, according to M. Planchon, that these were formerly indigenous to France before they were reintroduced by man as cultivated plants, a conclusion which Saporta thinks holds equally true of the walnut. The judas-tree occurs very sparsely at present in France, and appears chiefly in gardens, so that Saporta is doubtful whether it is really indigenous. In Pleistocene times, however, it grew abundantly in Southern France, and, as we shall see presently, ranged even as far north as the neighbourhood of Paris. It is the same with the manna-ash (*Fraxinus ornus*), now confined to Corsica and Italy, but formerly a widely-spread species in Southern France.

The tufas near Montpellier have yielded much the same assemblage of species as those of Provence; they evidently form part of one and the same flora, but Planchon mentions twelve species which Saporta has not yet detected in the tufas of Provence.[1]

From the above summary it will be gathered that the most remarkable characteristic of the Pleistocene flora of Provence and Montpellier was the intimate association of still indigenous species with species which have ceased to be so—some of these last having retreated because unable to support the cold of winter, while others have retired to the mountains to escape the dryness of summer. We must therefore conclude with Count Saporta, that at the time when all those species lived together in the same region the climate must have differed from that of the present. It was necessarily somewhat cooler, or at least more equable, in order that *Laurus canariensis* might flourish abundantly, and at the same time more humid to enable Salzmann's pine, the Pyrenean pine, the dwarf pine, the wych elm (*Ulmus montana*), the gray willow (*Salix cinerea*), the beech, the lime, and others to live along with the laurel. In other words, the summers were not so dry, and the winters were milder. The flora of the Italian tufas betokens a similar climate. At the time when that flora occupied the low grounds of Central Italy the climate must have been exempt from extremes. It is well that the reader should keep these conclusions in mind. Had the Pleistocene Period been characterised by strongly-contrasted summer and winter seasons, as some geologists maintain, it is obvious that the tufas should have furnished us with a very different suite of plants.

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[1] I give here Count Saporta's list of the plants discovered in the tufas of Provence :—

I. Cryptogamia.—*Pellia epiphylla?* Nées; *Scolopendrium officinale*, Sm.; *Adiantum capillus-veneris*, L.

II. Monocotyledons.—*Cyperaceæ?*—impressions of leaves like those of *Carex maxima*, L.; *Typha latifolia*, L.

III. Dicotyledons.—*Pinus pumilio*, Haenke; *Pinus Salzmanni*, Dun.; *Pinus pyrenaica*, Lap.; *Corylus avellana*, L.; *Ulmus campestris*, Sm.; *U. montana*, Sm.; *Celtis australis*, L.; *Ficus carica*, L.; *Populus alba*, L.; *Salix cinerea*, L.; *S. alba*, L.; *Laurus nobilis*, L.; *L. canariensis*, Web.; *Fraxinus ornus*, L.; *Viburnum tinus*, L.; *Hedera helix*, L.; *Vitis vinifera*, L.; *Cornus sanguinea*, L.; *Clematis flammula*, L.; *Tilia europæa*, L.; *Acer opulifolium*, Vil.; *A. monspessulanum*, L.; *A. campestre*, L.; *Euonymus europæus*, L.; *Juglans regia*, L.; *Rhus cotinus*, L.; *Pyrus acerba*, D.C.; *Cratægus oxyacantha*, L.; *Rubus idæus*, L.; *Cercis siliquastrum*, L.

M. Planchon gives a list of thirty species, amongst which the following have not been obtained in the Provençal tufas :—*Fegatella conica*, Cord.; *Pteris aquilina; Smilax aspera; Alnus glutinosa; Quercus ilex; Buxus sempervirens; Phillyrea angustifolia; P. media; Fraxinus excelsior; Rubia peregrina; Ilex aquifolium; Cotoneaster pyracantha.* It may be added here that the tufa of the valley Aygalades, near Marseilles, has yielded remains of *Elephas antiquus*, which were determined by Falconer and Lartet.

Coming north to the valley of the Seine, we find still more striking botanical evidence in favour of an equable climate having prevailed in Pleistocene times. Near the village of La Celle, not far from Moret, above the confluence of the Seine and Loing, occurs an accumulation of tufa which, from the character of its fossil contents and from its relation to the Pleistocene river-deposits of the Seine which it overlies, is unquestionably of Pleistocene age. It has yielded to the researches of M. Chouquet many plant-remains and shells, the former of which have been described by Saporta, who gives this list of species :—

1. *Scolopendrium officinale.*
2. *Corylus avellana*, L., common hazel.
3. *Populus canescens*, Sm., common white poplar.
4. *Salix cinerea*, L., gray willow.
5. *Salix fragilis*, L., brittle willow.
6. *Ficus carica*, L., fig-tree.
7. *Laurus nobilis*, L., var. *canariensis*, Webb, Canary laurel.
8. *Fraxinus excelsior*, common ash.
9. *Sambucus ebulus*, L., Dane-wort or dwarf-elder.
10. *Hedera helix*, L., common ivy.
11. *Clematis vitalba*, L., clematis.
12. *Buxus sempervirens*, L., box.
13. *Acer pseudo-platanus*, L., sycamore.
14. *Euonymus europæus*, L., European spindle-tree.
15. *Euonymus latifolius*, L., broad-leaved spindle-tree.
16. *Prunus mahaleb*, L., perfumed cherry-tree.
17. *Cercis siliquastrum*, L., judas-tree.

This group, as Saporta proceeds to point out, indicates a former geographical distribution very different from that which now obtains. The fig-tree, the Canary laurel, the box, and others, are no longer indigenous to the region round Paris. In

France the box at present hardly passes north beyond the environs of Lyons, and certainly does not grow spontaneously north of the rocky plateau of the Côte d'Or,[1] the broad-leaved spindle-tree is arrested at the Jura, the judas-tree does not occur north of Montélimart, the fig-tree is not indigenous beyond Provence, and the Canary laurel exists in a wild state, as already stated, only near Toulon, in the most southern part of the Department of Var. Mingled with all these species are others which serve to distinguish the flora of Moret from that of the tufas of Southern France. Among these is the sycamore (*Acer pseudo-platanus*), a tree of Central and Northern Europe, which occurs in the Alps but does not extend south into the Mediterranean region, where its place is taken by *Acer opulifolium*, Vill. It is widely spread in the shady woods of Central and Northern France, of Switzerland, and Germany. This tree, the relics of which occur plentifully in the tufa of La Celle, cannot be grown successfully in Provence, where many attempts have been made to introduce it. It languishes under the hot dry summer of the south, and very rarely reaches an adult stage. The common ash is another of the trees which, like the sycamore, is no longer associated with those southern forms along with which it formerly grew in Northern France. It is almost excluded from the Mediterranean region, but abounds in Central France, and extends north to Southern Sweden. In the tufas of Southern France and Italy its place is taken by the manna-ash (*Fraxinus ornus*, L.) Now this very remarkable assemblage of plants tells a tale which there is no possibility of misreading. Here we have the clearest evidence of a genial, humid, and equable climate having formerly characterised Northern France. The presence of the laurel, and that variety of it which is most susceptible to cold, shows us that the winters must have been mild, for this plant flowers during that season, and repeated frosts, says Saporta, would prevent it reproducing its kind. It is a mild winter rather than a hot summer which the laurel demands, and the same may be said of the fig-tree. The olive, on the other hand, requires prolonged summer heat to enable it to perform its vital functions. Saporta describes the fig-tree of the La Celle tufa as closely approximating, in the size and shape of its leaves and fruit, to that of the tufas in the south of France, and to those of Asia Minor, Kurdistan, and Armenia. But if the winters in Northern France were formerly mild and genial, the summers were certainly more humid and probably not so hot. This is proved by the presence of several plants in the tufa of La Celle, which cannot endure a hot arid climate, but abound in the shady woods of Northern France and Germany. It was, as Saporta remarks, a combination of clement winter with pronounced humidity, which accounts for the association at La Celle of the fig-tree, the Canary laurel, and the sycamore. We may note, however, that notwithstanding the equableness of the climate, the difference of latitude between Paris and Provence is yet clearly evinced by the flora of the tufas. Thus the common ash and the sycamore, which are plentiful in the tufa of La Celle, are wanting in the travertine deposits of the south, where they are represented, as we have seen, by the manna-ash, now only indigenous in Corsica and South Italy, and by *Acer opulifolium*, which has retired from the low grounds of Provence and taken refuge in the hilly parts of the Mediterranean region.

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[1] According to Hooker the box is indigenous in Belgium.

According to Professor Crié, the flora of the travertine deposits of Mamers (Sarthe), which likewise owe their origin to the action of incrustating water, approaches in character to that of La Celle. The deposits in question have not yet been exhaustively examined, but M. Crié mentions among the plants yielded by them the hornbeam (*Carpinus betulus*, L.), the elm (*Ulmus campestris*, L.), the oak (*Quercus robur*, L.), the gray willow (*Salix cinerea*, L.), the hazel (*Corylus avellana*, L.), and the hart's-tongue (*Scolopendrium officinale*, Sm.) Besides these there occurs the impression of a leaf, which appears to be that of the fig-tree. The general facies of the flora, the same observer remarks, implies a milder and more equable climate than now characterises the west of France.[1]

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[1] *Les Anciens Climats et les Flores Fossiles de l'Ouest de la France*, p. 61.

The tufas of Canstadt, near Stuttgardt, have yielded the following species, which are common to the similar deposits of Southern Europe :—

Scolopendrium officinale (hart's-tongue).
Quercus pedunculata (oak).
Fagus sylvatica (beech).
Corylus avellana (common hazel).
Ulmus campestris (elm).
Populus alba (white poplar).
Salix cinerea (gray willow).
Cornus sanguinea (common dogwood).
Acer pseudo-platanus (sycamore).
Buxus sempervirens (box).
Euonymus europæus (spindle-tree).
Tilia grandifolia (lime).

The total number of species is twenty-nine, of which three are extinct, namely the mammoth oak (*Quercus mammouthii*), a poplar (*Populus Fraasii*), and a walnut tree, which, according to Heer, resembles the American black walnut (*Juglans nigra*) and butter-nut (*J. cinerea*) in the toothed pinnæ of its leaves. With the exception of these extinct forms and the box, all the species met with in the tufa still occur in Würtemberg. The sycamore, however, and the whortleberry, which is also common to the tufa, are not found now in the neighbourhood of Canstadt, the former growing on the mountains and the latter in peat-bogs. Heer thinks that the climatic conditions implied by the flora of the tufa are similar to those now prevalent in the same locality, but Saporta points out that the difference between the Canstadt flora and that of Southern Europe in the Pleistocene Period was really much less than it is at present. Several species which nowadays are found in the Mediterranean region only in the mountains, such as the beech, the lime, the maple, the sycamore, etc., descended in Pleistocene times to the low grounds of Middle Italy. The vegetation of Würtemberg was distinguished from that of Southern Europe chiefly by the presence of firs, and by the absence of the more southern forms, such as vine, fig, judas-tree, laurustinus, etc. But, as we have seen, out of a total number of twenty-nine species in the Canstadt tufa, no fewer than twelve are common to the tufas of the low grounds of Southern Europe. These facts indicate, as Saporta has maintained, a climate more equable and humid than the present. In short, the facts are in perfect keeping with the conclusions to which the same botanist has come after a careful study of the Pleistocene floras of Northern France and the Mediterranean region. If, therefore, we were to draw our inferences solely from those tufa deposits, we should be compelled to conclude that the climate of our continent during the Pleistocene Period was singularly genial. The winters must have been very mild, and the atmosphere humid, to have permitted that peculiar distribution of plants which is evinced by the tufas of Central and Southern Europe. But, as we shall learn presently, there are certain accumulations of Pleistocene age which appear to contradict these conclusions in the most emphatic manner.

M. P. Fliche has described[1] a lignite of Pleistocene age which occurs at Jarville, not far from Nancy, and thus as near as may be in the same latitude as the tufa of La Celle. In this lignite we not only find no trace of any southern species, but the whole flora has a markedly northern facies. The trees mentioned by M. Fliche are birch (probably *Betula pubescens*, Ehrh.), green-leaved alder (*Alnus viridis*, Z.), mountain-pine (*Pinus montana*, Du Roi), larch (*Larix europæa*), spruce (*Picea excelsa*), *Pinus obovata*, and what seem to be juniper and yew—all species which occur in Middle Europe only at high elevations and in northern regions. The same lignite has yielded a number of remains of insects, which are likewise northern forms. They are *Agonum gracile*, Sturm; *Bembidium nitidulum*, Marsh.; *B. obtusum*, Sturm; *B.* sp.; *Patrobus excavatus*, *Mononychus pseudacori*, Fabr.; *Adimonia?*

In Switzerland, near the railway station of Schwerzenbach (Canton of Zurich), a peat-bog has yielded a flora of a still more pronounced northern character.[2] The peat itself is only a few feet in thickness, and contains oak in its upper part, with pine lower down. Between the peat and the clay upon which it rests occur leaves of *Betula alba* and pine cones, and in the uppermost layers of the clay leaves of *Myriophyllum*, *Dryas octopetala*, dwarf birch (*Betula nana*), and *Salicés* appear, along with wing-cases of beetles. A little lower down in the clay are found leaves of the netted-leaved willow (*Salix reticulata*) and Arctic willow (*Salix polaris*), the latter being a characteristic Spitzbergen plant. Certain peat-bogs of Bavaria have yielded similar evidence of colder climatic conditions, and we are supplied with still more remarkable testimony to the same effect by the well-known tufa and peat of Schussenried in Swabia.[1] This peat contains northern and high-alpine species of mosses, such as *Hypnum sarmentosum*, which ranges north to Lapland and Greenland; *H. aduncum* and *H. fluitans* var. *tenuissimum*, which is a high-alpine and Arctic American form. Such a flora is quite in keeping with the character of the shells and the mammalian remains which occur in the tufa commingled with relics of Palæolithic man. The shells are well-known "löss" forms, of which I shall speak later on, while the mammalian remains belong to reindeer, glutton, Arctic fox, etc.

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[1] *Comptes Rendus de l'Acad. des Sciences*, t. lxxx. p. 1233.

[2] Nathorst, *Öfversigt af Kongl. Vetensk.-Akad. Förhandl.*, 1873, No. 6, p. 15.

Mr. Nathorst,[2] a well-known Swedish geologist, has followed the spoor of the old arctic flora from Southern Sweden into Denmark and England, and through Germany to Switzerland. In Mecklenburg, as in Switzerland and Bavaria, he has detected in certain freshwater clay-deposits leaves of the dwarf birch (*Betula nana*), and the white or common birch (*B. alba*), associated with shells of northern forms. But the peat-bogs of Northern Europe belong to a somewhat later date than those lignites and turbaries of the central and southern regions to which I have specially referred, and they need not therefore be considered at present.

The tufas of the south of Europe, as already described, give evidence of a more equable and humid climate than the present, which allowed certain trees, now banished to the uplands, to flourish in the low grounds, but they nowhere contain an arctic flora. Nevertheless, we are not without botanical testimony in favour of a colder climate having obtained in Italy in Pleistocene times, for trunks of the Siberian or Cembran pine (*Pinus cembra*) occur in the old peat-bogs of Ivrea. The same species has been found also in certain deposits near Mur in Styria. Again, the Scots fir (*Pinus sylvestris*) occurs in peat, beside Lake Varese, and in travertine in the Abruzzi, but nowadays it is well nigh restricted to dry localities in the Alps, that range from 300 to 2000 mètres of elevation.[1] But the testimony of the plants is supplemented by that of the mollusca, and the whole evidence leads up to one conclusion, from which, as it seems to me, there is no possibility of escaping.

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[1] O. F. Fraas, *Württemb. Jahreshefte*, Bd. xxiii. (1867), p. 48; *Archiv für Anthropologie*, Bd. ii. (1867); *Compt. Rend. du Congrès d'Anthrop.*, 1869, p. 286.

[2] *Öfversigt af K. Vet.-Akad. Förh.*, 1873, No. 6, p. 11 *et seq.*

The tufas and marls of La Celle, which have yielded so interesting a series of vegetable remains, contain also many shells which have been studied in detail by M. Tournouër, who gives the following list of species :—[2]

* ?	1.	*Limax sp.* ? ; common.	
	2.	Eggs of . . ?	
** ?	3.	*Hyalinia, sp.* ?	
** ?	4.	—	cf. *H. glabra*, Stud. ? ; common.
* ?	5.	—	cf. *H. dutaillyana*, Mab.?
	6.	—	*radiatula*, Alb.
	7.	—	*crystallina*, Müll.
**	8.	*Zonites acieformis*, Klein ; common.	
	9.	*Helix* (*Patula*) *rotundata*, Müll., var.	
	10.	—	(*Anchistoma*) *obvoluta*, Müll. ; rare.
	11.	—	(*Theba*) *pulchella*, Müll.
*	12.	—	(*Petasia*) *bidens*, Chemn. ; rare.
	13.	—	(*Trichia*) *hispida*, Linné.
*	14.	—	(*Monacha*) *limbata*, Drap. ; rare.
**	15.	—	(*Eulota*) *chouquetiana*, Tourn. ; common.
	16.	—	(*Chilotrema*) *lapicida*, Linné ; rare.

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[1] Sordelli, *Atti Soc. Ital. Sci. Nat.*, t. xvi. p. 350.

[2] In this list those species which are preceded by an asterisk (*) are no longer indigenous ; two asterisks (**) signify that the species is extinct.

17. — (*Arionta*) *arbustorum*, Linné ; abundant.
18. — — — , var.
19. — — — , var.
20. — (*Pentatœnia*) *nemoralis*, Linné ; common.
21. — — — , var.
22. — — *hortensis*, Müll.
23. — (*Helicella*) *ericetorum*, Müll., var.
** 24. — (*Candidula*) *Radigueli*, Bourgt.? ; common.
* 25. *Bulimus montanus*, Drap. ; rare.
26. *Zua lubrica*, Müll.
27. *Pupa* (*Pupilla*) *muscorum*, Linné.
28. — (*Sphyradium*) *doliolum*, Brug.
29. *Vertigo* sp. ?
30. *Clausilia* (*Marpessa*) *laminata*, Mont.
* 31. — (*Iphigenia*) *dubia*, Drap.? ; rare.
32. — — *parvula*, Stud. ; abundant.
33. — — — , var.
34. *Succinea putris*, Linné, type ; rare.
35. — — , var.
36. — — , var.
37. — — , var. *limnoidea*, Picard ; abundant.
38. — — , var. *gigantea*, Baudon.
39. — *Pfeifferi*, Rossm.?, var. *contortula*, Baudon.
** 40. — *joinvillensis*, Bourg. ; rare.
41. *Limnœa ovata*, Drap.
42. — sp. ?
* 43. *Pomatias septemspirale*, Razoum.
** ? 44. *Cyclostoma elegans*, Müll., var. *lutetiana*, Bourgt.?; abundant.
45. — — , opercula.

This list shows at a glance that the molluscous fauna of La Celle presents strong contrasts to that which is now characteristic of Northern France. The number of extinct forms, and of species and varieties which have emigrated, and the absence of certain forms which are characteristic of the fauna now occupying the same region—alike conspire, as M. Tournouër remarks, to separate the fauna of La Celle from that of the present day. The species are arranged by him in four groups as follows :—

1. Species still living in the district where the tufa occurs.

2. Species which have retired from the district, but are still natives of France.
3. Species which do not now occur in France, but are living in other parts of Europe.
4. Species which are extinct or entirely exotic.

The great majority of the shells belong to the first group, the most common and most characteristic by reason of its abundance being *Helix arbustorum*. Group 2 is represented by *Helix limbata*, which is common in the lower Pyrenean region, and in the south-west of France, but much rarer in the region of the Loire and Normandy. It has not been cited as occurring in the neighbourhood of Paris. Another migrated species is *Bulimus montanus*, which has retired to the hillier parts of France; it is found also in the Jura, the Alps, and the Pyrenees. *Clausilia dubia* has a similar distribution; *Pomatias septemspirale* has not been met with in the region round La Celle; it occurs, however, in the valley of the Oise, etc., and is common in all the hilly regions of the east. It is noteworthy, says M. Tournouër, that these three last-mentioned species have their present head-quarters rather towards the east, and outside of France than in France itself. Under the third group comes *Helix bidens*, a form which is no longer met with in Western Europe. It has been cited as occurring in the Alps, but M. Tournouër thinks this determination is more than doubtful. It is widely distributed in Eastern and North-eastern Europe, from Croatia, Hungary, and Transylvania to Sweden and Russia. One of the most remarkable forms of the fourth group is the large zonites (*Zonites acieformis*). This shell belongs to a group which is foreign to Northern France and similar latitudes in Europe, and is no longer represented in the western regions of our continent. The forms to which it most nearly approaches (*Zonites verticillus*, Fer., and *Z. croaticus*, Partsch) are natives, the one of Austrian Tyrol, from which it extends into Bavaria, and the other of Croatia. Other extinct species are *Succinea joinvillensis*, *Helix chouquetiana*, *H. Radigueli*, *Cyclostoma lutetiana*, etc.

The inferences drawn by M. Tournouër as to the climatic conditions implied by the molluscan fauna of La Celle are precisely the same as those deduced by Count Saporta from a study of the flora. The geographical distribution of the shells, so different from that which now obtains, and the former wider diffusion of certain forms, lead to the conclusion that the climate of Northern France was formerly more equable, so as to permit species, now widely separated, to live together. That it was also a humid climate is proved by the general facies of the shells, nearly all of them terrestrial, and the great majority such as live in damp and shady places, some in humid woods about the foot of trees, others upon marsh-plants and mosses, under stones, or in moist earth.

A somewhat similar suite of shells occurs in certain ancient river-deposits of the neighbourhood of Paris, which are known to geologists as "diluvium gris." M. Bourguignat gives a list of 76 species, of which 36 are land-shells—the most abundant forms being *Helix nemoralis, H. arbustorum, Helix pulchella, Succinea putris, Bulimus montanus, Pupa muscorum*, etc., all of which occur in the beds at La Celle. They are associated as at La Celle with *Succinea joinvillensis, Cyclostoma lutetiana,* and other extinct forms, and with exotic species such as *Helix bidens.*[1]

The calctufa and alluvial deposits of Canstadt in Würtemberg, contain, according to Klein, 50 species of land-shells, and 21 of river-shells. Of these 50 species he recognises 36 as still living in the same region, 10 as occurring beyond it, but still indigenous to Europe, and 4 as extinct. The species which are most abundant are *Helix arbustorum, H. nemoralis, H. obvoluta, H. pulchella, H. hispida,* etc., *Succinea putris, Bulimus montanus, Clausilia parvula, Pupa muscorum, Pomatias septemspirale,* etc., which occur along with *Helix bidens,* and some extinct species, such as *Zonites aciciformis,* and *Succinea elongata,* Braun,—a form closely approaching to *S. joinvillensis.*

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[1] For lists of shells in French river-deposits, see *Mémoire sur le diluvium de Viry-Noureuil et les fossiles qu'il renferme* (Paris, 1864), by l'Abbé Lambert; *Bull. Soc. Géol. France,* 2 Sér., t. xvii. p. 68; Belgrand's *La Seine,* t. i. p. 202.

There is thus a strong analogy between the deposits at La Celle and Canstadt, as M. Tournouër has pointed out. Their faunas are characterised by the similar proportion of the same elements, and by the presence especially of the extinct *Zonites* and the *Succinea*, together with *Helix bidens*.

In the Pleistocene fluviatile deposits of England occur three well-known river-shells, *Cyrena fluminalis, Unio littoralis,* and *Hydrobia* (*Paludina*) *marginata,* which are common also in the beds of the same age in northern France. None of those three species is extinct, but they have all disappeared from the living fauna of Britain. *Cyrena fluminalis,* indeed, is now no longer a native of Europe, but still lives in the Nile, the Lake of Tiberias, and the streams of Cashmere. *Unio littoralis* is found in the waters of the Seine and the Loire, but *Hydrobia marginata* has forsaken the rivers of Northern France and retired to those of the south and south-west, and to the Jura and Switzerland.

We have thus strong testimony furnished by the land- and freshwater-shells as to the former prevalence, during some part of the Pleistocene Period, of a more humid and equable climate than the present; a climate characterised above all by the mildness of its winter. But just as an examination of the old flora has compelled us to admit that the climatic conditions were not continuously genial throughout Pleistocene times, so shall we be led presently to similar conclusions by a study of the mollusca.

Professor F. Sandberger, who is a well-known authority in the study of land- and freshwater-shells, supplies us with a number of facts, which seem at first to be strongly at variance with the results obtained by MM. Klein and Tournouër. He has recently given an interesting account[1] of certain Pleistocene deposits in the neighbourhood of Würzburg, in Franconia, from which I take the following list of shells:—

1. *Limneus truncatulus,* Müll.; very rare. Living in Franconia. Europe generally, and Siberia; in Heligoland it is the only snail.

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[1] *Verhandl. der physicalisch-medicinischen Gesselschaft in Würzburg, N. F.,* Bd. xiv. 1879.

2. *Pupa parcedentata*, A. Braun ; rare. Extinct ; akin to the high-alpine form, *P. Sempronii*, Charp.
3. *Pupa muscorum*, L. sp. ; abundant. Living in Franconia. Europe generally and Siberia.
4. *Pupa columella*, G. v. Martens ; rare. High Alps, Lapland, and Russia.
5. *Clausilia dubia*, Drap. ; very rare. Living in Franconia. Middle Europe.
6. *Clausilia pumila*, Ziegl. ; very rare. Living in Franconia. Middle Europe.
7. *Clausilia parvula*, Stud. ; abundant. Living in Franconia. Middle Europe generally.
8. *Clausilia laminata*, Mont. ; very rare. Living in Franconia. Europe, with the exception of the Arctic Regions.
9. *Cionella lubrica*, Müll. sp. ; very rare. Living in Franconia. Europe generally and Siberia.
10. *Chondrula tridens*, Müll., sp. ; rare. Living in Franconia. Middle and Southern Europe.
11. *Helix arbustorum*, L. ; abundant. Living in Franconia. Middle and Northern Europe.
12. *Helix sericea*, Drap. ; very abundant. Living in Franconia. Middle and South Germany (Alps).
13. *Helix striata*, Müll., var. *nilssoniana*, Beck ; rare. Middle and North Germany, Sweden ; the variety in Oeland.
14. *Helix strigella*, Müll. ; very rare. Living in Franconia. Europe generally, Siberia.
15. *Helix pulchella*, Müll. ; rare. Living in Franconia. Europe generally, Siberia, North America.
16. *Helix tenuilabris*, A. Braun ; very rare. Siberia, Alps, Swabian Alb.
17. *Helix fruticum*, Müll. ; very rare. Living in Franconia. Europe (with the exception of British Islands), Ural, Altai.
18. *Succinea oblonga*, Müll. ; very abundant. Living in Franconia. Rare in Middle Europe, with the exception of the higher mountains (Black Forest, Alps) ; very common in Scandinavia and Russia.
19. *Succinea putris*, L. ; rare. Living in Franconia. Europe generally, and Siberia (here it attains its largest size).
20. *Limax agrestis*, L. ; rare. Living in Franconia. Europe generally, Siberia, and North America.

Of these twenty species there are seventeen which still live in Franconia; but many of the latter, Dr. Sandberger says, are varieties which differ greatly from those that characterise the

Pleistocene deposits (löss) of Würzburg. The *Helix fruticum*, for example, which now lives in Franconia, is much larger and has a thicker shell than the sub-fossil variety, and the same holds true of *Helix strigella*. On the other hand, *Cionella lubrica* and *Pupa museorum* are now represented by smaller forms. It is only in high mountains and in northern latitudes that we meet with the varieties of these and other species which appear in the Würzburg deposits. But the cold climatic conditions thus implied are rendered still more apparent when we learn that *Helix striata* occurs only in the Swedish form, that *Helix tenuilabris* and *Pupa columella* are now restricted to northern regions, and that the extinct *Pupa pareedentata* comes nearest to a high-alpine species.

Man is represented in the same deposits by only one small finger-bone, and the associated mammalian remains do not contradict the evidence supplied by the shells. Dr. Sandberger chronicles 36 species, which he arranges as follows :—

Not yet sufficiently determined		8 species.
Hyperborean	*Cervus tarandus* (reindeer).	7 „
	Gulo luscus (glutton).	
	Myodes obensis[1] (Siberian lemming).	
	„ *torquatus* (torquated lemming).	
	Arvicola ratticeps (northern field-vole).	
	„ *gregalis* (Siberian social-vole).	
	Spermophilus altaicus (Altai pouched-marmot)	
East European	*Alactaga jaculus* (jerboa)	2 „
	Arctomys (*? bobac*) (marmot).	
Extinct	*Hyæna spelæa*[2] (cave-hyæna).	6 „
	Ursus spelæus (cave-bear).	
	Bos primigenius (urus).	
	Bison priscus (extinct bison).	
	Elephas primigenius (mammoth).	
	Rhinoceros tichorhinus (Siberian rhinoceros).	
Living now or within historical times in Franconia		13 „
		36

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[1] Added in MS. by Dr. Sandberger since the publication of his paper.

[2] The cave-hyæna is believed to be the progenitor of the living *Hyæna crocuta*, from which it differs chiefly in size.

The same author has given us an account of the fauna discovered in the Pleistocene deposits of the Rhine valley.[1] In that region the löss has yielded an assemblage of shells somewhat similar to that of the Würzburg list. Many of them are high-alpine and hyperborean forms, and the general facies of the group is decidedly northern. Mr. Prestwich, a number of years ago, drew attention to the fact that certain high-level river-deposits of Pleistocene age in the valleys of Southern England and Northern France furnish a group of shells which have not only a very wide range, but one more in a northern than a southern direction; and he remarked that the general absence of southern species from the deposits in question was also not without its significance.[2]

M. Locard has recently shown that in the Quaternary or Pleistocene deposits of the neighbourhood of Lyons northern forms of molluscs preponderate, the boreal species being commingled with many which are still indigenous to that part of France.[3]

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[1] *Ausland*, 1873, p. 984; *Geological Magazine*, Dec. ii. vol. i. p. 215.

[2] *Philosophical Transactions*, Part II., 1864, p. 279.

[3] See *Description de la Faune Malacologique des Terrains Quaternaires des Environs de Lyon.* The species he mentions are as follows:—

Limax, species undetermined.
Testacella haliotidea, Drap.
Succinea putris, L.
S. elegans, Risso.
S. oblonga, Drap., var. *ragnebertensis*, Loc.
S. joinvillensis, Bourg.
Hyalina lucida, Drap.
H. nitida, Müll.
H. septentrionalis, Bourg.
H. subnitens, Bourg.
H. hyalina, Féruss.
H. crystallina, Müll.
Helix rotundata, Müll.
H. obvoluta, Müll.
H. pulchella, Müll.
H. costata, Müll.
H. fruticum, Müll.
H. strigella, Drap.
H. new species.
H. hispida, L.
H. locardiana, P. Fagot.
H. neyronensis, P. Fagot.
H. steneligma, Bourg.
H. claverana, Mabille.
H. carthusiana, Müll.
H. ericetorum, Müll.
H. costulata, Ziegl.
H. striata, Drap.
H. unifasciata, Poiret.
H. lapicida, L.
H. arbustorum, L.
H. nemoralis, L.
H. hortensis, Müll.
H. sylvatica, Drap.
? *H. pomatia*, L. (very doubtful).
Bulimus montanus, Drap.
B. detritus, Müll.
B. tridens, Müll.
? *B. quadridens*, Müll.

I shall refer to only one other example—the fossiliferous breccias of Corsica, which have been described by the same author.[1] He gives a list of nineteen land-shells as occurring in the breccias which extend along the east coast of the island, from Furiani, south of Bastia, to Cape Corso. They are :—

Helix aspersa, Müll.
„ *aperta*, Born.
„ *nuculoides*, Debaux.
„ *vermiculata*, Müll.
„ *Raspaillii*, Payr.
„ *broccardiana*, Dutailly.
„ *hospitans*, Bonelli.
„ *halmyris*, Mab.
„ *variabilis*, Drap.
„ *apicina*, Fér.
Helix galloprovincialis, Drap.
„ *hydatina*, Fér.
„ *hispida*, Müll.
Zonites obscuratus, Porro.
„ *Blauneri*, Shuttl.
„ *lathyri*, Mab.
Pupa quadridens, Drap.
„ *cinerea*, Drap.
Clausilia Kusteri, Rossm.

All these are still living in Corsica, but some of the species which occur very abundantly in the breccia are now met with sparingly in only a few limited localities. Thus, among others, *Helix broccardiana*, which is extremely common throughout the

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Ferussacia lubrica, Müll.
Cæcilianella acicula, Müll.
Clausilia parvula, Stud.
Pupa muscorum, L.
P. frumentum, Drap.
Vertigo columella, G. v. Martens.
Carychium minimum, Müll.
Planorbis albus, Müll.
P. crosseanus, Bourg.
P. nautileus, L.
P. arcelini, Bourg.
P. carinatus, Müll.
P. marginatus, Müll.
P. vortex, L.
P. rotundatus, Poiret, var. *rhodanicus*, Loc.
P. contortus, L.
Limnæa auricularia, L.
L. limosa, L.
L. gerlandiana, new species, closely approaching *L. frigida*, Charp.
L. peregra, Müll.
L. stagnalis, L.
L. palustris, Müll.
L. truncatula, Müll.
Ancylus lacustris, L.
Cyclostoma elegans, Müll.
Bythinia tentaculata, L.
B. similis, Drap.
Amnicola ? sp.
Valvata alpestris, Brauner.
V. piscinalis, Müll.
V. obtusa, Studer.
V. arcelini, Bourg.
V. minuta, Drap.
V. planorbulina, Palad.
V. cristata, Müll.
Neritina fluviatilis, L.
Sphærium corneum, L.
Pisidium henslowianum, Shep.
P. amnicum, Müll.
P. casertanum, Poli.
P. nitidum, Jenyns.
P. pusillum, Gmel.

[1] *Archives de Muséum d'Histoire Naturelle de Lyon*, 1873 ; *Bull. Soc. Géol. France*, 3 Sér. t. i. p. 232.

breccias, is found at present only in a few cold and shady spots. The breccia at Toga has yielded also human bones associated with abundant remains of a pika or tailless hare (*Lagomys corsicanus*), a fact which strongly favours M. Locard's view that the climate of Corsica during some part of the Pleistocene Period was colder and wetter. The bones of this lagomys are found at a height of less than 250 feet above the sea, yet it belongs to a family which is now restricted to boreal regions, or to the lofty mountains of warm and temperate climates. A few marine shells occur in the breccia, where they have evidently been left by man. According to M. Locard, the breccia of Bonaria, near Cagliari, in the south of Sardinia, in which Sig. Studiati has found *Lagomys sardus* similarly associated with marine shells, has been accumulated under precisely the same conditions as the breccia of Toga.

Thus a general review of the evidence afforded by the plants and molluscs of the Pleistocene deposits strongly supports the conclusions that seem forced upon us by an examination of the mammalia. We have distinct proofs that the Pleistocene Period was characterised by very considerable changes of climate. At one time the conditions were mild and genial, at another time they were very much the reverse. The hypothesis of violently-contrasted summers and winters which some writers have supported[1] is thus seen to have no foundation in fact. Even if we could suppose it possible that hippopotamuses and reindeer might have wandered to and fro across the whole breadth of

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[1] See Lyell's *Antiquity of Man*, pp. 207-209. W. B. Dawkins: *Popular Science Review*, 1871, p. 388; *Quart. Journ. Geol. Soc.*, vol. xxv. p. 192; xxviii. p. 410; *Cave-hunting*, p. 397. In later writings Professor Dawkins seems to have lost faith, to some extent, in the theory of seasonal migrations, and to have partially adopted that of secular migrations; see especially *Early Man in Britain*, p. 112, where, if I do not misunderstand him, he now endeavours to maintain both views at once. For additional arguments against the view of seasonal or yearly migrations, see Lubbock's *Prehistoric Times*, 4th ed. p. 315; J. Geikie, *Geol. Mag.*, vol. ix. p. 164; x. p. 49; *Great Ice Age*, chap. xxxviii. Professor Prestwich has maintained that the ossiferous and Palæolithic river-deposits were accumulated during colder conditions than the present—see *Phil. Trans.*, 1864, p. 277,—while an opinion exactly opposite has been supported by several French writers, as by M. d'Archiac (*Leçons sur la Faune Quaternaire*).

Europe in one season, we should yet be compelled to admit that no such theory of migrations can account for the presence of two widely-divergent floras and molluscous faunas in the Pleistocene deposits of Middle Europe; they, at least, could not have indulged in such feats of travel. The flora and fauna of La Celle introduce us to conditions of climate such as are only partially reproduced now along the borders of Western France, where, in the same and even higher latitudes, thanks to the genial influence of the ocean, many southern species of plants are successfully cultivated. Thus we meet with the fig-tree of Brittany, the evergreen oak of Noirmoutier and of Quimper, and the arbutus of Vendée. Along the whole coast of Brittany, even as far as Brest, not only the fig-tree and the laurel, but the myrtle, grow in the open air, attain a good size, and ripen their fruits. The presence of the delicate Canary laurel at La Celle, however, shows that in Northern France the winter season of the genial period during which that laurel flourished must have been as clement as that of Var in the extreme south. Count Saporta has described a picturesque scene which met his view near Montmeilan (Var), where the Fontaine-l'Évêque tumbles into the Verdon. The conditions, he says, vividly recalled those which must at one time have obtained at La Celle. Wild fig-trees of small stature overhung the water, which threw itself down a rock decked with a rich vegetation. The leaves of this tree exactly resembled those of La Celle, and the figs which still remained on the wood of the preceding year were of small size, and dropped away at the least touch into the water. The group of plants around the waterfall closely approached to the flora of La Celle. Besides the fig-tree, Saporta noted common hazel, gray willow, elder-tree, ivy, clematis, box, and spindle-tree. The common ash and the sycamore, however, were both wanting, for neither occurs in that part of Provence at so low an elevation. The laurel (*Laurus canariensis*) was also absent, its northern limit as an indigenous plant stopping much farther to the south. The genial climate which nourished the flora of La Celle extended, as we have seen, east into Germany, nor can there be any doubt that the climate of Europe generally at that time was equable and humid. Clement winters and cool summers permitted the wide diffusion and intimate association of plants which have now a very different range—temperate and southern species like the ash, the poplar, the sycamore, the fig-tree, the judas-tree, the laurel, etc., overspread all the low grounds of France as far north at least as Paris. It was under such conditions that the elephants, rhinoceroses, and hippopotamuses, and the vast herds of temperate cervine and bovine species ranged over Europe, from the shores of the Mediterranean up to the latitude of Yorkshire, and probably even farther north still; and from the borders of Asia to the Western Ocean. Despite the presence of numerous fierce carnivora—lions, hyænas, tigers, and others—Europe at that time, with its shady forests, its laurel-margined streams, its broad and deep-flowing rivers,—a country in every way suited to the needs of a race of hunters and fishers,—must have been no unpleasant habitation for Palæolithic man.

This, however, is only one side of the picture. There was a time when the climate of Pleistocene Europe presented the strongest contrast to those genial conditions—a time when the dwarf birch of the Scottish Highlands, and the Arctic willow, with their northern congeners, grew upon the low grounds of Middle Europe. Arctic animals, such as the musk-sheep and the reindeer, lived then, all the year round, in the south of France; the mammoth ranged into Spain and Italy; the glutton descended to the shores of the Mediterranean; the marmot came down to the low grounds at the foot of the Apennines; and the lagomys inhabited the low-lying maritime districts of Corsica and Sardinia. The land- and freshwater-shells of many Pleistocene deposits tell a similar tale; boreal, high-alpine, and hyperborean forms, are characteristic of these accumulations in Central Europe; even in the southern regions of our continent the shells testify to a former colder and wetter climate. It was during the climax of these conditions that the caves of Aquitaine were occupied by those artistic men who appear to have delighted in carving and engraving.

I have already pointed out that severe conditions supervened towards the close of the Pleistocene Period, so that a cold climate followed after one that had been eminently mild and genial. We are not to suppose, however, that the change was sudden. It was brought about, in all probability, in the most gradual and imperceptible manner throughout a long course of years. The climate would become slowly deteriorated, the southern flora retreating south, the arctic advancing from the north. Of the mammalia, the hippopotamus, we may reasonably suppose, would be amongst the first to retreat from the valleys of England, France, and Germany; but the hardier temperate forms would linger on so long as they had sufficient food-supplies, and where deer and oxen abounded, the carnivora would not be wanting. Some of the upholders of the migration-hypothesis lay much stress upon the circumstance that bones of the reindeer have been found with the marks of hyænas' teeth upon them. If these marks be really due to the hyæna and not to some other carnivore, the fact will only help to prove that the cave-hyæna was endued with the same elasticity of constitution as the lion and the tiger, and would be likely to occupy any territory where there was a good supply of beef and venison.

We must now turn our attention to the more purely geological evidence, when I hope to show that the conclusions we have now arrived at are not only not contradicted but amply supported by an impartial consideration of the physical conditions under which the Pleistocene deposits were accumulated.

CHAPTER V.

CAVE-DEPOSITS OF THE PLEISTOCENE PERIOD.

Caves of different kinds—Mode of their formation—Absence of Pliocene organic remains in European caves—General character of cave-accumulations—Commingling of human relics with remains of extinct mammalia—"Break" between Palæolithic and Neolithic times—Stalagmite, its formation and rate of growth—Mr. Pengelly's observations on stalagmitic accretion in Kent's Cavern—Stalagmitic growth not continuous—Calcified earth, sand, and gravel in caves—Angular blocks, *débris*, and breccia in caves—Succession of deposits in Brixham Cave—Professor Prestwich on the geological history of that Cave—Contemporaneity of man and the old mammalia—Extreme antiquity of Pleistocene Period.

Having glanced at the general character of the relics of the Old Stone Period, and acquired some knowledge of the various groups of animals which are believed to have been contemporaneous with our Palæolithic predecessors, we may now proceed to consider the nature of the evidence upon which that belief is based. With this question is naturally involved that of the antiquity of the deposits in which the Old Stone implements and mammalian remains are entombed.

These deposits occur very frequently in caves and rock-fissures, and they are also met with covering considerable areas in certain river-valleys, both in this country and the Continent. We shall consider first the evidence supplied by the cave-accumulations, after which we shall be better prepared to understand what geologists have to tell us about the ancient fluviatile accumulations of the Pleistocene Period.

For my purpose it is not necessary to go into the subject of the formation of caves. Most of the large and important caves occur in calcareous strata, those which have been excavated in other kinds of rock being as a rule of little consequence. Nearly all owe their origin to the chemical and mechanical action of the subaerial forces—rain, frost, and running-water, while a few have been formed in other ways. There are some rare instances, for example, where a lava-stream has flowed over and solidified above a mass of snow and ice, and the subsequent melting of the latter has left a hollow behind. Again, during earthquakes rocks are frequently rent asunder, and when these fall rudely together, irregular cavities are left between the disjointed masses. Similar results often take place when great landslips occur. But such cases are exceptional, and need not at present occupy our attention; the caves which are of most interest to the student of Palæolithic times are those which have been more or less slowly excavated in the body of the rocks themselves. Caves of this character are of two kinds;—there are some which have been formed at the surface and in the light of day, while others have been hollowed out at various depths by the action of underground water. Those of the former class are generally of smaller size than the others, and are typically represented by the hollows that occur at the base of many inland cliffs, and by the sea-caves that are so commonly met with along the present coast-line, and in the rocks at higher levels where the waves and breakers in former times have been busy at their work of erosion. As a rule the hollows at the base of inland cliffs mark the outcrop of some softer or more easily disintegrated rock than the others with which it is associated. When a hard unyielding stratum overlies a softer or more readily decomposed bed, the latter will crumble away and be worn back by the mere action of the weather, and hollows of this nature may of course occur either at the base of a cliff or steep slope, or at any intermediate level between the base and the top. Should such a soft rock happen to be washed by some stream a hollow of considerable size may be scooped out, and this will continue to be enlarged so long as the weather acts and the water flows, until the overhanging harder stratum gives way and topples down, and the cave is, for the time being, obliterated. For the formation of such hollows, however, it is not necessary that the strata should consist of unequally-yielding materials. Cliffs of homogeneous composition are often undercut by streams, simply by mechanical erosion, but this action of the running-water is frequently much intensified by the influence of frost. Of the mode of formation of sea-caves it is not necessary to speak. They and the more or less shallow rock-shelters and hollows, that occur in the face and at the foot of inland cliffs and steep slopes, may of course be excavated in almost any kind of rock.

The second class of caves includes all the most extensive underground galleries, many of which ramify in almost every direction, winding tortuously about, and often opening on either side into similar intricate hollows, which in like manner communicate with lateral extensions of the same character. All these cavities owe their origin to the action of underground water. The chemical composition of mineral springs might have led us to expect that the more soluble strata must frequently be honeycombed and excavated to a very considerable extent, for the amount of mineral matter which many of those springs carry to the surface in solution is simply astonishing. We cannot be surprised therefore when we find that here and there the surface of the ground has subsided, the rocks having been undermined by the continuous action of underground water. Subsidences of this nature are most commonly met with in districts where the prevailing strata are calcareous, but they also occur in regions where rock-salt is plentiful. But since calcareous strata are more widely diffused, and as a rule occupy more continuous tracts than any other kind of readily-soluble rock, it is in countries where the former abounds that underground cavities attain their greatest development. These have been excavated by the chemical action of acidulated water, assisted doubtless in many cases by contemporaneous and subsequent mechanical erosion; that is to say, the cavities have been enlarged by the filing action of the sand and gravel which the underground streams have swept along. For a large proportion of our great limestone-caves are simply the deserted channels of subterranean streams and rivers. Many such water-courses are well known at the present day, and the direction of some of them can be traced by the swallow-holes, chasms, and "sinks," which indicate where the roofs of the cavities have given way, or have been pierced by acidulated water. In certain regions almost all the drainage is thus conducted underground—rivers after flowing for a considerable distance at the surface suddenly disappear below the ground, and follow a hidden course for it may be many miles before they reappear. Sometimes, indeed, they never come to the surface again, but enter the sea by subterranean channels. Should anything occur to interrupt such a system of underground drainage, and the streams and rivers be compelled into new channels, the old subterranean courses will then become more or less dry galleries, which may be accessible by one or even by several openings. And although in time these entrances may become blocked by the fall of *débris*, yet atmospheric erosion—rain, frost, and running-water—will by and by open up new ones, either by the gradual disintegration and removal of rock, or by inducing more or less sudden falls and landslips.

It would be interesting to ascertain, if that were possible, the age or date of origin of our great limestone-caves. But that, it is to be feared, we shall hardly be able to accomplish. We may indeed infer with much probability that some caves are older than others, but no geologist can say with certainty at what particular time the larger caverns in this and other countries were first open to the light of day, and fitted to become the resort of wild beasts and men. Ever since the limestones have been permeated by water trickling down from the surface, the excavation of caves has been going on, and there is no reason, therefore, why some of the underground galleries in the more ancient limestones (such as those of Devonian and Carboniferous age) may not date back to a period anterior to the deposition of the younger Tertiary formations. Nevertheless, it is remarkable that none of our great caverns has yet yielded deposits of older date than the Pleistocene Period—that is to say, the time when Europe was tenanted by Palæolithic man and the old mammalia. We cannot doubt that those caves were in existence in the preceding Pliocene Age, and that many (perhaps most) were as open to the day then as in early Palæolithic times. Yet if this were so, why is it that they do not contain abundant remains of the old Pliocene mammalia, or even of the animals that were characteristic of the still earlier Miocene Period? Professor Boyd Dawkins has suggested that the caves which were accessible in Miocene and Pliocene times may have been destroyed by the agents of erosion before the beginning of the Pleistocene Period, and certainly the thickness of rock, which has been peeled off the face of the country and carried in the form of gravel, sand, and mud into the sea since the close of the Miocene Period, is so enormous that there may well be much truth in Mr. Dawkins's suggestion. Indeed, as regards any bone-caves of Miocene age, it may be strongly doubted whether they could possibly have existed down even to Newer Pliocene times; for the denudation which can be shown to have taken place before the beginning of the Pleistocene Period would more than suffice to account for the total disappearance of many extensive caves, carved out of much more durable rocks than limestone. But I do not think that Mr. Dawkins's hypothesis accounts equally well for the total absence from our caves of Pliocene bone-accumulations. The Pliocene Period was not separated by any prolonged interval from the succeeding Pleistocene Age. Quite the contrary, as we know, was the case, for some of the mammals of the former period lived on into the latter, and their remains are found commingled with those of typical Pleistocene species in the floor-deposits of the caverns. Although we admit as a possibility that the caves which were accessible in early Pliocene times may have disappeared prior to the advent of the great body of the Pleistocene fauna, yet we find it hard to believe that the same could have been the case with all the caves which may have been visited by the Pliocene mammals during the later stages of that period. It would be very strange indeed if denudation should have removed every Pliocene cave, and at the same time opened out a completely new suite of caverns for the use of the Pleistocene fauna. The appearances presented by the oldest accumulations in our great limestone-caves shows that these latter were not only in existence, but had attained pretty much their present dimensions before they were resorted to by Palæolithic man and his congeners; and we can hardly resist the conclusion, therefore, that many of them must have been as accessible in Pliocene times as they subsequently became. And if they were thus accessible at that early period, it is almost certain that they must at one time have contained accumulations of Pliocene age. No trace of these, however, has yet been detected; but this need not surprise us, because, as we shall presently learn, there is every reason to believe that the caves have frequently been invaded by running-water, and their floor-deposits broken up and swept away. Before the neighbouring valleys had been excavated to their present depth such accidents would be liable to occur whenever the streams and rivers rose in flood. We know that some of the valleys in question were deepened to the extent of fifty and even of a hundred feet and more during the Pleistocene Period, so that in the preceding Pliocene Age and in early Pleistocene times the caves opening into these valleys would be more exposed to irruptions of water than they were at a later date. When the Pleistocene Period was far advanced many of the caves seem to have remained permanently dry, and the accumulations of floor-deposits continued with little or no interruption. Had the rivers continued to flow at the same level all through the Pleistocene Period, it is more than probable that no considerable floor-deposits would have escaped destruction. In the sequel we shall find that there is abundant evidence to show that some of the older cave-accumulations have experienced no little denudation. The caves would appear to have been cleared out again and again. And if this has been the actual fate of Pleistocene accumulations, we need not wonder at the apparently entire absence of Pliocene cave-deposits. It is quite possible, however, that some vestiges of these may yet be detected, when some of the larger caves have been exhaustively explored.

The floor-accumulations present in most cases very much the same kind of phenomena. Lying at the immediate surface are usually found relics of modern and archaic times—tools, implements, and ornaments of iron, bronze, or polished stone; and with these are often associated remains of ox, deer, sheep, dog, horse, and other animals that are still indigenous to Europe. Such modern and archaic relics and remains frequently rest upon an undisturbed pavement of *stalagmite*, underneath which again often occurs a variable thickness of earth, more or less abundantly charged with the bones, teeth, and horns of extinct or no longer indigenous mammals, and now and again yielding Palæolithic implements in larger or smaller numbers. Occasionally the floor-deposits underlying the modern superficial layer may consist of a vertical succession of half-a-dozen different beds, lying perfectly undisturbed, one above another; in all of which Palæolithic implements and remains of the extinct mammalia may be found. When a cave is completely filled up, the upper or more modern layer is often wanting. Sometimes the only deposit covering the floor of a cave consists of a rude breccia of limestone and earth, disseminated through which relics and remains of the Old Stone Age may be detected. But in each and every case where Neolithic, Bronze, or Iron implements are present they invariably occur at the very surface. It is true that now and again the cave-deposits have been disturbed in Neolithic and more recent times, and relics belonging to different periods have thus got mixed. But such cases are not so common as one might have expected, and with the wider experience we have now gained, they are always more or less easily detected. When the layers show no trace of disturbance the Palæolithic deposits invariably occur underneath those of Neolithic and later times, and not only so, but the one set of deposits is sharply marked off from the other. When we clear away the superficial layer with its Neolithic and more modern relics, and dig into the underlying Palæolithic deposits, we pass, as it were, into quite a different world. The domestic animals—ox, sheep, dog, and horse—disappear, and we are confronted by elephants, rhinoceroses, hyænas, mammoths, reindeer, and so forth.

Thus in Britain and North-western Europe there appears to have been no gradual passage from Palæolithic into Neolithic times. We know that the men of the Old Stone Age occupied our continent along with many large pachyderms and carnivores, and that a time came when all these animals, together with Palæolithic man, vanished from the European area, and were abruptly succeeded by Neolithic man and the present indigenous fauna. There is thus a gap or hiatus in the cave-history,—the floor-accumulations contain apparently no record of the period that intervened after the departure of Palæolithic man and before the advent of his Neolithic successor. But this remarkable fact will come out more clearly as we further consider the evidence.

The fact that human relics are commingled in many caves with the remains of extinct animals has long been known to geologists. But for a number of years it was a disputed point whether man had actually been contemporaneous with such animals or not. And though several investigators, who had made careful examinations of the cave-accumulations, stoutly maintained that he had, yet geologists generally continued sceptical and unbelieving. But after such caves as that at Brixham (Torbay), and the still more famous cavern near Torquay, called Kent's Hole, had been subjected to long and careful examination under the auspices of the Royal and Geological Societies, and the British Association, even the most sceptical hammerer threw aside his doubts. But while giving all due credit to the Exploration Committees for their admirable and exhaustive work, we must not forget that the main result of their labours has been merely to verify and confirm the conclusions arrived at by the earlier investigators. It is needless to say that those who have taken the most active share in cave-exploring are the readiest to admit this; and none more willingly than Mr. Pengelly, who has personally superintended the investigations carried on in the two famous Devonshire caves. It was in one of these (Kent's Hole) that the first discovery in cave-deposits of the association of human implements with the remains of the extinct mammalia was made. This important "find" occurred to the Rev. J. MacEnery, who, between the years 1825 to 1841, seems to have explored Kent's Cavern with great assiduity. It is not my intention, however, to enter into the history of discovery in this most interesting department of geology. At present I am concerned merely with the general results arrived at. Those who are desirous of acquiring fuller details than can be given in these pages may consult the treatises mentioned in the note below.[1] In some of these works references will be found to the labours of the earlier investigators, and the reader will be able to form an opinion as to what extent the conclusions of such men as MacEnery, Buckland, Schmerling, Marcel de Serres, Christol, Tournal, and others have been borne out by the more detailed and systematic researches of later days.

The mode in which human relics and mammalian remains are associated in the undisturbed floor-deposits of the caverns leaves one in no doubt that man and the extinct animals were actually contemporaneous—that is to say, that they occupied the European area during one and the same period. Human relics and mammalian remains occur commingled in certain cave-earths that are sealed up by an overlying, unbroken, and continuous layer of stalagmite. Below this upper cave-earth, again, may occur a second cave-earth containing similar relics and remains, and separated from the "earth" above by a second uninterrupted pavement of stalagmite. It is perfectly certain, therefore, that the caves were occupied alternately by wild beasts and savage men for longer or shorter periods. And as if to make assurance of their contemporaneity doubly sure, we have the strong evidence of the Palæolithic carvings and etchings, to which reference has already been made. No one now questions the fact that man lived through all those remarkable geographical and climatic changes to which the old mammalia bear testimony. This is one of the questions which has passed out of the category of mere ingenious conjecture and plausible inference into that of well-assured and demonstrated fact. I need not, therefore, pause to recontrovert the views of those who have maintained that the stone celts are mere natural productions; that the "worked flints" have been chipped into their present forms by the action of frost, or by knocking about in the beds of rivers, or by any of the manifold modes in which rocks are broken up and disintegrated by natural forces. To those who have been used almost daily during many years to handle naturally-broken stones of all kinds, and to break and chip them for themselves, such views necessarily appear futile and inconsequent, the peculiar chipping to which the flints have been subjected pointing unmistakably to man's handiwork. "No man," Professor Ramsay remarks, "who knows how chalk-flints are fractured by nature would doubt the artificial character of these ancient tools or weapons." Several eminent geologists, however, compassionating the difficulties of less experienced observers, have replied in detail to the objections which were at one time raised to the human origin of the "worked flints." That task having been accomplished, no one now doubts the artificial origin of these implements any more than one disbelieves that man's hands made the bone-needles, awls, and harpoons, or etched the remarkable outline-sketches of mammoth and reindeer.

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[1] Buckland's *Reliquiæ Diluvianæ;* Lyell's *Antiquity of Man;* Lubbock's *Prehistoric Times;* Dupont's *L'Homme pendant les Ages de la Pierre;* Lartet's and Christy's *Reliquiæ Aquitanicæ;* Le Hon's *L'Homme Fossile en Europe*, and Boyd Dawkins's *Cave-hunting.* A general account of the English bone-caves is given in the last edition of Ramsay's *Physical Geology and Geography of Great Britain.* For more detailed accounts of the mode of occurrence of cave-accumulations, see Mr. Pengelly's *Annual Reports to the British Association* on the excavations which are now being carried on in Kent's Cavern; and Mr. Tiddeman's Reports on the Victoria Cave, near Settle. Another most elaborate and valuable Report is that by Professor Prestwich on the exploration of Brixham Cave. See *Philosophical Transactions*, vol. clxiii. 1873, p. 471. Mr. MacEnery's manuscripts were lost for a number of years; an abstract of them, however, was published in 1859 by Mr. Vivian, and ten years later so much of the MSS. as had been preserved was printed in full by Mr. Pengelly in the *Transactions of the Devonshire Association.*

Let us now glance at the evidence which the cave-accumulations furnish as to the prolonged duration of the Old Stone Age. I have mentioned the fact that frequently the floors of the great limestone-caverns are paved with a material called *stalagmite,* in and underneath which the relics of Palæolithic man and his congeners are often met with in abundance. The general appearance of this deposit must be familiar to most. It is a carbonate of lime which may be loose and friable in texture, or harder and more coherent, but in many cases it is dense and crystalline. It varies also in colour from creamy white to yellow and red, being stained by the oxides of iron and vegetable matter. The mode of its formation is very simple. Rain-water invariably contains some proportion of carbonic acid, and as it sinks through the soil, which is often enough charged with decaying organic matter, it may take up more before it reaches the underlying rocks. Such acidulated water filtering downwards into the cracks and crevices that seam a bed of limestone, immediately attacks the rock, and carries away a certain portion in solution. By and by the now calcareous water oozes out on the roof of a cave, where as the drops gather and fall they are of course subject to evaporation. Thin shells or pellicles are thus deposited on the roof, and corresponding accretions form on the floor. By the continual prolongation of the tiny shells from above long pendent stalactites are formed, while cakes and rounded bosses, domes and mammillated heaps, grow upwards, as it were, from the ground. If this process goes on uninterruptedly, the time comes when the stalactites and stalagmites meet, so as to form fantastic pillars reaching continuously from floor to ceiling.

In most cases these calcareous accretions are of slow growth, an inch or two requiring, as a rule, many years for their formation, but sometimes they form more rapidly. A good deal depends upon the quantity and quality of the percolating water, and also upon the character of the limestone. Where the soil is well charged with organic matter, the water that finds its way down into the rocks being highly acidulated will dissolve limestone rapidly. But if the rainfall in such a case be not great, then the dissolution of the rock may not take place so briskly as in another district where the percolating water, although less acidulated, is yet more plentiful.

Again, owing to differences of composition and structure, all calcareous rocks are not equally acted upon by carbonated water, some being more readily dissolved than others. Hence it is evident that we cannot take the rate at which stalagmite accretes in one particular cave as a standard of measurement by which to judge of the time required for the accumulation of a certain thickness of stalagmite in any other cave, unless we are quite sure that the conditions are now and have for a long time been the same in both, which it need hardly be said is never likely to be the case. For instance, it is a well-known fact that, owing to the humidity of our climate, marble monuments exposed to the weather, especially in or near our manufacturing towns, are very soon corroded; while in other countries, with more favourable atmospheric conditions, the same stone may be subjected for a much longer time to the action of the weather without showing much appreciable wear. And if this be true of the calcareous rocks exposed at the surface of the ground, it must also hold good for the limestone, chalk, and marble that are buried below our feet. Were the climate of Britain drier than it is, there can be little doubt that our limestones would decay, and stalactites and stalagmites would form, more slowly than they do at present. But even under such conditions the calcareous rocks would weather away, and stalagmites would accrete at very diverse rates, owing, as I have said, partly to differences in the quantity and quality of the percolating water, and partly also to differences in the composition, porosity, and structure of the limestones. Observations have put it beyond doubt that the rate at which stalagmite increases is very variable. In some instances the drip has taken many years to form a mere thin glaze the fraction of a line in thickness, while in one case (Ingleborough Cave) a layer nearly a quarter of an inch in thickness has accreted in one year. This latter, however, is probably very exceptional. Had stalagmitic accretions generally increased at this rate, all our caves ought to have been long ago filled up with them.

Obviously, therefore, no reliable conclusion can be drawn as to the rate at which stalagmites have grown in caves generally, from measuring the rate of growth in any particular cave at the present time. To form an adequate conception of the age of a given bed of stalagmite we ought to measure, if possible, the rate at which that individual bed is now accreting. This, if it be carefully determined, will not necessarily give us a perfectly true result; but when certain considerations, to be mentioned presently, are kept in view, it will enable us to make some approximation to that end. It is well known that during the exploration of Kent's Cavern near Torquay a number of names and dates, carved upon the uppermost bed of stalagmite, have been detected, and some of these go back to the beginning of the seventeenth century. Yet, as Mr. Pengelly tells us, "though the stalagmitic matter has been continually accreting on them ever since, it has been at so slow a rate that the inscriptions are still perfectly legible." On the surface of a large boss of stalagmite which rises up from the general level of the floor, and thus marks a spot where the drip has been more continuous, and the growth, therefore, more rapid than in many other parts of the cave, there is this inscription, "Robert Hedges, of Ireland, Feb. 20, 1688." The film of stalagmite which has formed over it is not more than the twentieth of an inch in thickness, nor have we any direct evidence to show that the accretion of this particular boss was more rapid in earlier times. The bed of which it forms a part is of very variable thickness, being hardly an inch in some places, while in others it swells out to as much as five feet. If, therefore, we took the rate at which the large boss in question has accreted during the past two centuries as a standard of measurement, we should infer that the upper layer of stalagmite began to form about 240,000 years ago, while the underlying layer, which occurs in the same cave and attains a thickness of twelve feet, would at a similar rate require some 576,000 years for its growth. But these rates are certainly excessive, for they are based on the assumption that past climatic conditions did not differ from the present. As we shall see in the sequel, however, this is very far from having been the case, for we have every reason to believe that at certain epochs during the Pleistocene Period the rainfall was considerably greater than it is now. At present the rainfall near Torquay is about 35 inches, but in former times it may have been three or four times as much, or even greater still. With a rainfall of 140 inches the stalagmites would accrete, other things being equal, four times as rapidly, so that one inch might form in 1000 years. At that rate the upper stalagmite would require 60,000 and the lower bed 144,000 years respectively for their growth.

In other parts of the cave, however, we have evidence to show that the stalagmite has sometimes accreted at a more rapid rate. Thus, overlying a superficial layer containing remains of Romano-Saxon times, we find a thin interrupted cake of stalagmite which nowhere exceeds six inches in thickness, and is generally much thinner, or absent altogether. Assuming, therefore, that six inches as a maximum have accreted in 2000 years, and using this comparatively rapid rate as a standard of measurement for the older stalagmitic pavements, we should still have a period of 20,000 years for the formation of the upper layer, and of 48,000 years for the lower. But on the supposition that, owing to an excessive rainfall, the stalagmites formerly increased four times more rapidly than they do now, the first period would be reduced to 5000 years, and that of the lower stalagmite to 12,000 years.

We have no grounds, however, for believing that the Pleistocene Period was characterised throughout by such an excessively wet climate. I shall have occasion to refer in the sequel to the evidence bearing upon the former occurrence of a rainy climate, and hope to be able to show that a succession of wet and less humid periods alternated during Pleistocene times. Now, although the rainfall in some of those wet periods may have been considerably in excess of what I have supposed merely for the sake of illustration, yet on the other hand it may have come short of it, while the intervening drier periods might well have experienced a rainfall not much greater than that of the present. Thus it is evident that the present rate of stalagmitic accretion in Kent's Cavern cannot be safely relied upon as a standard by which to judge of the time required for the formation of the old pavements, underneath which the Pleistocene cave-earths lie buried. The question of age, as we see, is not so easily settled, for we have to take into account the effects produced by previous climatic conditions; and as we can form only a more or less uncertain estimate of these effects, it is impossible that our conclusions can be other than vaguely approximative. Even on the most extravagant assumption, however, as to the former rate of stalagmitic accretion, we shall yet be compelled to admit a period of many thousands of years for the formation of the stalagmitic pavements in Kent's Cavern.

There is another consideration, however, which must not be forgotten when we are endeavouring to form some adequate conception of the time required for the accretion of such stalagmitic pavements. We have no reason to suppose that their growth has always been continuous; on the contrary, we know very well that in many cases the accretion on the floors has frequently been interrupted. Sometimes the caves were filled, or partially filled, with water, and their former occupants expelled for prolonged periods, during which no growth of stalagmite could take place. At other times, when the caverns were the frequent resort of large predatory animals like the bear, such pellicles of stalagmitic matter as formed upon the floor would often be trampled on and commingled with earth and clay, which might be readily removed when, now and again, flood-waters found access to the caves, so that any particular bed of stalagmite can seldom or never represent the entire quantity of carbonate of lime that dropped in solution upon the floor from the time when the stalagmitic pavement first began to accrete.

This is clearly indicated by the structure of the stalagmitic pavements themselves. Sometimes these are remarkably pure and homogeneous, indicating a prolonged and perhaps continuous period of deposition. Now and again, however, we find them showing numerous intercalations of earth—some of which certainly point to the former presence of muddy water. An excellent example of this was met with during the exploration of Brixham Cave, in one part of which six or seven plates of crystalline, compact, soil-stained, finely-laminated stalagmite, varying from half an inch to upwards of an inch and a half in thickness, extended horizontally from wall to wall, one over the other, and alternated with an equal number of interstratified layers of earth of similar thickness. Again, stalagmites, so far from being always comparatively pure, are often so highly impregnated with earthy ingredients as to assume the character of calcified earths. Such impurities may have been introduced in various ways. Most limestones when they are dissolved in carbonic acid leave a red residue behind, and there can be little doubt that much of the earthy matter in stalagmitic accretions is of this nature, and to that we may add the red earth, mud, and silt introduced by rains and freshets through fissures in the roofs and sides of caves, and even in many cases by their more open mouths. Some of the caves in the Rock of Gibraltar bear evident marks of having been invaded in this manner. The heavy rains that fall on the western slopes of that ridge rush down the rocky declivities, sweeping before them considerable quantities of red earth, derived from the subaerial decomposition of the limestone, and much of this muddy water escapes into underground cavities through narrow fissures, and now and then pours into the caverns by their chief entrances. Finally, when we conceive of the caves as having frequently been the actual abodes during long periods of various wild beasts and men, we can have no difficulty in understanding how stalagmitic accretions might come to be soil-stained, even although rain and freshets never found access to them at all.

I have mentioned the fact that stalagmites often pass into what might be termed calcified earths, and from what has been said about the origin of such impurities the reader will be prepared to learn that frequently the floors of our old limestone-caves are buried under considerable accumulations of gravel, sand, and earth or clay. The presence of these deposits shows that sometimes the caves after they had been resorted to by animals again became the channels of engulphed streams, either intermittently or for long continuous periods; while, in other cases, they were ever and anon liable to be inundated by floods carrying into them quantities of mud and silt. Moreover, it can be shown that sheets of stalagmite have occasionally been broken up and removed from certain caves, in whole or in part, so that we cannot always be sure that this may not have happened in the case of many other caves.

Throughout all the cave-deposits occur, more or less frequently, large and small angular fragments of limestone that have evidently fallen from the sides and roof. Sometimes these are scattered pretty equally through the floor-accumulations, at other times they are perhaps more numerous at some levels than at others. They seem also to be present most abundantly in the chambers or galleries that open directly to the day, or which can be shown to have formerly had some such direct connection with the external atmosphere. It is also to be noted that the uppermost layer in which any traces of Pleistocene mammals and Palæolithic man are met with, is not unfrequently sprinkled with numerous fallen masses, and sometimes with a more or less thick *breccia* of large and small fragments of limestone, by which the mouth or entrance to the cave is occasionally blocked up.

The fragments may have been detached from the roof in various ways. It cannot be doubted that, as Mr. Pengelly has pointed out,[1] the gradual widening of the joints in limestone by the corrosive action of percolating water must occasionally loosen large blocks, and allow these to fall away; and as percolation is always going on, such accidents as the sudden dislodgment of fragments may take place at any moment, in any part of a cave, and under any conditions of climate. Again, it is not improbable, as some have suggested, that the tremor of the ground during an earthquake might shake down many halfloosened blocks and fragments. But such will hardly account for all or even for any great proportion of the scattered blocks and thick aggregations of limestone-*débris* that are met with in so many caves. I am inclined to believe that very many of these fragments may have been dislodged by the action of frost, which at some epochs during the Pleistocene Period was certainly more intense in our latitude than it is now. This would account for the more abundant presence of fallen blocks and *débris* at and near the entrances of caves, for in the deeper recesses the cold would necessarily be less intense, and less capable therefore of rupturing the limestone and detaching angular fragments. If the dislodgment of all these fragments had been due solely to the corrosive action of percolating water or to the vibrations of earthquakes, we should be at a loss to understand why the greatest falls should have so frequently taken place in those portions of the caves that are most accessible to the influence of the external atmosphere.

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[1] *Trans. Devon. Assoc.*, vol. vii. 1875, p. 315.

Reference has been made to the fact that deposits of gravel, sand, and earth frequently occur in caves, sometimes underlying and not uncommonly intercalated with sheets or pavements of stalagmitic matter. The history of these accumulations often impresses us fully as much as that of the stalagmites themselves with the length of time required for their formation. One or two examples may suffice to show what is meant. The first I shall cite is that of Brixham Cave, which has been carefully explored by a committee of well-known geologists and archæologists.[1] This cave occurs on a little hill overlooking the small fishing-town of Brixham, Torbay, and its entrance is about 95 feet above high water. The deposits met with consisted of the following accumulations, which are named in descending order:—

1. *Stalagmitic Floor* of irregular thickness, varying from a few inches to upwards of one foot.

2. *Breccia*, consisting of small angular fragments of limestone, cemented together by carbonate of lime. This deposit filled up the northern entrance

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[1] "Report on the Exploration of Brixham Cave, etc.," by Joseph Prestwich, F.R.S., F.G.S., etc. *Philosophical Transactions*, 1874, p. 471.

to the cave, from which it thinned off rapidly inwards, so that its surface formed an inclined plane.

3. *Black Bed;* a thin layer of blackish matter, which Professor Prestwich describes as "peaty calcareous earth (or leaf mould?)." It contained some angular fragments of limestone, and did not exceed one foot in thickness. It was met with immediately under the breccia, but occurred nowhere else throughout the cavern.

4. *Cave-earth,* from two to four feet thick,—a reddish-brown, tenacious, clayey loam, with many angular and sub-angular fragments of limestone, which varied in size from very small bits up to blocks weighing a ton. Rounded pebbles of trap, quartz, and limestone, were also of common occurrence, and nodules of iron-ore were occasionally met with. Fragments of stalagmite, apparently portions of an old "floor," likewise appeared here and there.

5. *Shingle,* consisting mainly of pebbles of quartz, greenstone, grit, and limestone, mixed with small fragments of shale. With the sole exception of the limestone, all these pebbles are foreign to the hill in which the cave is excavated. Here and there the shingle is cemented into a conglomerate.

Throughout a considerable part of one of the main galleries appears what Mr. Pengelly has termed a "stalagmitic ceiling," which varies from six inches to upwards of a foot in thickness. It extends horizontally from wall to wall, and through the large holes that occur in it an unoccupied space of two feet or so is seen to separate it from the solid limestone-roof of the cavern. Firmly adherent to its under surface, were observed in several instances angular, sub-angular, and well-rounded fragments of old stalagmite, together with small pieces of quartz and limestone.

With the exception of the black bed, all the other accumulations on the floor of this cavern proved to be more or less fossiliferous, but the cave-earth was by far the richest repository of bones. Associated with the mammalian remains were found a number of "worked flints." The bones belong, according to Mr. Busk, to twenty or twenty-one species, namely, mammoth, woolly rhinoceros, horse, great ox, shorthorn ox, great red-deer, reindeer, roebuck, cave-lion, cave-hyæna, cave-bear, grisly bear, brown bear, common fox, common badger, hare, rabbit, lemming, water-rat, shrew.

Professor Prestwich, after carefully weighing all the evidence, comes to the following conclusions:—The shingle, which forms the basement-bed, may have been introduced by water flowing over the slates, grits, and shales that occur to the westward of Brixham. Owing to the small drainage-area and the impermeable nature of the rocks, this old stream would occasionally become dry; and at such periods the remains of the mammoth, horse, and ox, which occur in the shingle, might have been brought in at intervals by lions and hyænas and devoured on the spot—the bones showing evident marks of having been gnawed. At this period in the history of the cave, "the valley of Brixham and its tributaries, which then as now formed the channels of drainage of the district, must have been from 70 to 80 feet less deep than at present." "After the cave had become choked with shingle," continues Professor Prestwich, "the stream, either from that cause, or from the deepening of the channels outside, kept more in the main valley, and a period of quiet succeeded, during which a first bed of stalagmite was deposited immediately upon the bed of shingle." This is the stalagmite which Mr. Pengelly calls a "stalagmitic ceiling." Ere long it was broken up and the surface of the shingle-bed, upon which it rested, was lowered to the extent of from six to ten feet—effects which may have been produced, according to Professor Prestwich, "either by an irruption of water carrying away part of the shingle, and so undermining the stalagmite, or by the breaking-up of the stalagmite, and the settling-down of the shingle deeper into the fissures by earthquake-movements." In whatever way the change took place, there can be no doubt that the succeeding accumulation of cave-earth bears witness to very different hydrographical conditions. No shingle-bearing streams now entered the fissures, but the cave was habitually dry. Occasionally, however, it was visited by floods from the main stream of the Brixham valley, which deposited their silt upon the floor, and thus during successive inundations the so-called "cave-earth" gradually accumulated. The breaking up of the first bed of stalagmite, and the lowering of the surface of the shingle-bed, gave greatly increased room in the cave, and hence it became a place of resort for such animals as hyænas and bears, and was occasionally visited by Palæolithic man. By and by, when flood-water no longer reached the cave, the formation of stalagmite, which had been going on during the intervals between successive inundations, proceeded without interruption, and the remains of such predatory animals as continued to frequent the cave, together with the bones of their prey, became sealed up in the calcareous drip. Eventually, however, the entrances to the cave were closed with an accumulation of *débris*, and "from that time it ceased to be accessible, except to the smaller rodents and burrowing animals, and remained unused and untrodden until its discovery in 1858."

Here then we have evidence, first, of the contemporaneity of man and the old mammalia; and, second, of the extreme antiquity of the period during which they were in joint occupation of Southern England. At the time when the cave first began to be visited by the mammalia and Palæolithic man the valley of Brixham was 70 or 80 feet less deep than now; in other words, so long a time has elapsed since then, that the streams of that district have been able to excavate their beds in hard rock to a depth of not far short of 100 feet.

CHAPTER VI.

CAVE-DEPOSITS OF THE PLEISTOCENE PERIOD—*Continued.*

Succession of deposits in Kent's Cavern—Conditions during their accumulation—Evidence for prolonged duration of Palæolithic Period—Hyæna-dens in England—Kirkdale Cave and Wookey Hole—Bone-caves never tenanted by man or wild beasts—Victoria Cave, near Settle in Yorkshire—Succession of deposits in that cave—Glacial beds associated with Pleistocene deposits—Bone-caves of Belgium—General succession of deposits in these—Trou du Sureau—Relative position of Neolithic relics.

Reference has already been made to the stalagmitic pavements in Kent's Cavern, and we have learned something of what they have to teach us. Let us now glance for a little at the general succession of the beds amongst which those pavements are intercalated, and we shall find that the earth and mechanical accumulations of this cave are not less eloquent of changes implying the lapse of time than the similarly-formed deposits at Brixham.

In digging down into the floor-accumulations of Kent's Cavern the following beds were passed through, beginning with the uppermost or newest:—[1]

1. A layer of *Black Mould*, consisting to a large extent of vegetable *débris*, and varying in thickness from three inches to twelve inches. This

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[1] This cave is being explored at the instance of the British Association, under the personal superintendence of Mr. Pengelly, to whose yearly reports (*Brit. Ass. Reps.* from 1865) and other papers (published chiefly in the *Transactions of the Devonshire Association*) I am indebted for the notes given above. General accounts of the cave will be found in Lyell's *Antiquity of Man;* Lubbock's *Prehistoric Times;* Evans's *Ancient Stone Implements of Britain;* Boyd Dawkins's *Cave-hunting;* and other works.

mould lay between and amongst large blocks of limestone, some of which rested upon it.

2. *Granular Stalagmite,* frequently containing large blocks of limestone. Thickness, one inch to five feet.

3. *Black Band,* four inches thick, consisting mainly of small fragments of charred wood ; occurred only in one part of the cave, where it occupied an area of about 100 square feet.

4. *Cave-earth ;* a light red clay, with many small angular fragments and some large blocks of limestone ; of variable thickness ; excavated to a depth of four feet.

5. *Crystalline Stalagmite,* reaching in places about twelve feet in thickness.

6. *Breccia,* composed of sub-angular and rounded pieces of dark red grit, with some quartz pebbles, embedded in a sandy matrix of the same colour. This is the lowest and oldest of the deposits so far as yet known, but its base has not yet been reached by the explorations.

The uppermost deposit, the black mould, is of comparatively recent origin. It contains articles of stone and bronze, and remains of a number of animals, all of which are still found living in England. None of the human relics needs date much beyond Romano-British times, while many are certainly more recent. With the underlying beds, however, the case is very different. In the granular stalagmite were found "stones of various kinds, shells of cockles and cuttle-fish, impressions of ferns, charcoal, bones and teeth of bear, elephant, hyæna, rhinoceros, horse, fox, and man, with flakes and cores of flint." Human relics also occur plentifully in the black band, such as numerous flint tools and some implements of bone, namely an awl, a harpoon, and a needle having a well-formed eye. With these were associated burnt bones, and remains of ox, deer, badger, rhinoceros, hyæna, etc. The cave-earth abounds in animal remains, both of extinct and living species, and it also contains numerous relics of man's handiwork. Here occur bones and teeth of lion, bear, mammoth, rhinoceros, hyæna, etc., along with remains of reindeer, Irish elk, red-deer, wolf, fox, badger, glutton, beaver, and other animals. The crystalline stalagmite and the breccia have yielded numerous traces of the cave-bear, and in the latter deposit were found implements of flint and chert, "much more rudely formed, more massive, and less symmetrical in form," than those obtained from the cave-earth and black band. They have been made, says Mr. Pengelly, "by operating not on flakes, but directly on nodules, of which portions of the original surface generally remain." (See Plate A, Fig. 1, p. 11.)

A study of the mechanically-formed accumulations on the floor of Kent's Cave reveals the fact that between the time of its earliest and latest known occupation by Palæolithic man and his congeners, considerable changes must have taken place in the drainage-features of the neighbourhood. The breccia tells us of a time when the cave was now and again occupied by bears, and occasionally visited by savage men. During that period it would appear that water, flowing from some of the adjacent higher hills, ever and anon carried into the cave many fragments of red grit—a rock which does not form any part of the hill into which the cave opens; but before the crystalline stalagmite began to accrete, this process had altogether ceased—the drainage had been diverted, and no mechanical sediment found its way into the cave. Then, long subsequently, came a time of re-excavation, when the crystalline stalagmite was undermined to some considerable extent, and broken up — much, both of it and the underlying breccia, being carried away. After this the cave was again visited by predatory animals and by Palæolithic man; and now and then flood-waters, bearing fine mud and silt, found their way into the cave and spread their sediment over the floors of chambers and galleries. Such inundations were intermittent, and perhaps irregularly recurrent—long intervals of comparative quiescence allowing the drip from the roof to commingle with and calcify the floor-earth. During the slow accumulation of this earth, hyænas seem to have occupied the cave for long periods, and it was certainly also the haunt of other predatory animals, such as lions, bears, and the extinct tiger-like machairodus. Man was likewise at intervals a visitor, and possibly a resident while the cave-earth was forming. At all events he certainly was so during the accumulation of the black band—for this bed is neither more nor less than the old hearth on which his wood-fire burned, where he cooked his meals and warmed himself. Mr. Pengelly is of opinion that the men of the black band and cave-earth were a race further advanced in civilisation than the barbarians whose implements are got in the old breccia. The former, he reminds us, "made bone tools and ornaments—harpoons for spearing fish, eyed needles or bodkins for stitching skins together, awls perhaps to facilitate the passage of the slender needle through the tough, thick hides, pins for fastening the skins they wore, and perforated badgers' teeth for necklaces or bracelets." But nothing of this kind occurs in the breccia; the only implements found at that low level consisting of flint or chert, and being of a much ruder character than the worked flints of the cave-earth.

Thus all the evidence conspires to show the prolonged duration of the Old Stone Age, so far as that is represented in Kent's Cavern. We have first to take into consideration the time required for the gradual introduction of the basement-deposits of red grit and sand by running-water; then we have to conceive of a change in the hydrographical conditions of the neighbourhood, when the stream that now and then entered the cave was no longer able to do so; next we have to realise as best we can the length of time that is implied by the thick crystalline stalagmite. How many long centuries rolled past while that old pavement was slowly accreting no one can say, but that it represents a lapse of ages compared to which the time embraced by all tradition and written history is but as a few months, who that is competent to form an opinion can doubt? After a prolonged period of quiescence, water once more entered the cavern and re-excavated the older deposits; and after this process had ceased, mud and silt were spread at intervals over the floor of the cave by intermittent inundations. From this time on to the accumulation of the upper bed of stalagmite, the cave, as we have seen, was frequented by many animals, whose remains are not met with in the old breccia, while the men who now and then occupied the place appear to have been further advanced than the poor savages whose relics are found associated with the bones and teeth of bears in the bottom-deposits. All these changes imply time, and are indicative, perhaps, of great geographical mutations. Mr. Pengelly thinks it probable that during the occupation of the cave by the great bears of the breccia, Britain was an island, and that the hyæna and its congeners came at a later date, when our country formed part of the Continent. This is a question, however, to which we shall return by and by. For the present I am content if I can aid the reader in realising the fact of the prolonged duration of the Palæolithic Period.

I have made special reference to Brixham Cave and Kent's Hole because they were the first to be investigated with such care and scientific caution as were required to set at rest the vexed question as to man's contemporaneity with the extinct mammalia of Pleistocene times. Many other English caves have been examined, with the result of increasing our knowledge of the old mammalian fauna, and adding a few more touches to the picture of Palæolithic savage life. But the main features of the evidence may still be read in the successive floor-accumulations of the famous Devonshire caverns. We have seen that those caves now and again were occupied by hyænas, who dragged thither their prey, and left the floor encumbered with heaps of gnawed bones. Frequently their coprolites are very abundant, and now and again the walls of the narrower passages of a cave are rubbed smooth, as if by the constant passing to and fro of the hyænas, while the jaws and other bones that lay sunk in the floor are smoothed and polished by their tread. Hyæna-dens have been discovered in various parts of England, among which the most interesting are Kirkdale Cave, described by Dr. Buckland,[1] and Wookey Hole, near Wells, on the south side of the Mendip Hills, of which a graphic account is given by Mr. Boyd Dawkins.[2] The latter cave furnished abundant evidence of the former presence of Palæolithic man, who seems now and then to have driven out the hyænas, and occupied their den. A number of rudely-chipped flint and chert implements, and two bone arrow-heads, were found, and ashes and carbonised bones indicated the place where fires had been kindled and food cooked. "One fragment of bone in particular, belonging to the rhinoceros, had been calcined, and its carbonised condition bore unmistakable testimony that it had been burnt while the animal juices were present." During the alternate occupation of Wookey Hole by man and hyænas there appear to have been recurrent floods, which deposited mud upon the floor, and eventually completely blocked up the cave.

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[1] *Reliquiæ Diluvianæ*, p. 38.

[2] *Cave-hunting*, p. 295; see also *Quart. Journ. Geol. Soc.*, vol. xix. p. 260; *Proc. Manch. Lit. and Phil. Soc.*, vol. ix. (1870), p. 181.

It must not be supposed that all the bones in ossiferous caves have been introduced by man and wild beasts. In very many cases they have been washed in by water, and often enough some of the animals that roamed our country in Pleistocene times fell victims to natural pitfalls. For it must be remembered that subterranean galleries frequently communicate, by means of narrow crevices, pipes, and swallow-holes, with the surface, and in a country the rocks of which are largely calcareous such pitfalls are a fruitful source of loss to unfortunate cattle-owners in our own day. That many animals may have been trapped, as it were, in this way we may well believe, and the appearances presented by their remains is sometimes highly suggestive of such a fate. But as the subterranean cavities into which they fell were often swept either intermittently or continuously by engulphed streams, it is not surprising that entire skeletons are but seldom met with, and that ossiferous accumulations in such cavities as could hardly ever have been occupied either by man or beast usually consist of a pell-mell and tumultuous *débris* of earth, stones, and bones, many of which show traces of having been rolled about. It is by no means necessary to suppose, however, that all these have been introduced through natural pitfalls. It is a well-known fact that when beasts are sickly they often repair to streams to quench their thirst, and of course they often die there. Thus their bodies would frequently be floated off by the water in flood time, and carried into underground channels. Again, as we shall afterwards see, the Pleistocene Period was, at several epochs, characterised by extreme humidity, when all the small streams and larger rivers were subject to great inundations. Hence any remains lying loose at the surface would frequently be swept away and carried into subterranean channels, in the unequal depressions of which they would tend to accumulate. Afterwards, when such inundations became rare, or altogether ceased, and when, owing to changes in the drainage-system of a country, the old subterranean cavities were deserted for new channels, the ossiferous and earthy *debris* would gradually become sealed up by stalagmitic accretions.

Before leaving the English caves reference may be made to the very interesting Victoria Cave, near Settle, in Yorkshire, which exhibits at least four stages or layers, each with its own peculiar character. It occurs at a height of about 1450 feet above the sea and 900 feet above the river Ribble, which flows at the foot of the hill in which the cave occurs. The deposits met with in this cave are as follow:—[1]

1. *Romano-Celtic Stratum*, with Roman coins, pottery, and various objects of bone, such as spindle-whorls, beads, spoon-brooches, a tooth comb, etc., and numerous articles and ornaments in bronze, some of them enamelled in red, blue, yellow, and green. With these were associated bones of the Celtic shorthorn, goat, pig, horse, roedeer, stag, wild-duck, grouse, and domestic fowl. Professor Dawkins assigns this layer with much probability to the time of the evacuation of Britain by the Romans, when the Romanised Celts were forced to flee from their homes, "with some of their cattle and other property, and were compelled to exchange the luxuries of civilised life for a hard struggle for common necessaries."
2. *Neolithic Layer.*—"Five or six feet of what had at one time been loose talus, but was now bound together, though not very firmly," with calcareous matter. Underneath this old talus were found a bone harpoon,

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[1] The exploration of Victoria Cave has been conducted under the auspices of the British Association, and is reported on by Mr. Dawkins and Mr. Tiddeman. See *British Association Reports*, 1873 (by Mr. Dawkins), and 1874-1878 (by Mr. Tiddeman). See also *Geol. Mag.*, vol. x. p. 11, and another paper by Mr. Tiddeman in *Journ. Anthrop. Inst.*, 1878.

an ornamented bone bead, and three flint flakes—all of which are referable to the Neolithic Age.

3. *Upper Cave-earth.*—This is a buff-coloured, rather stiff clay, abundantly charged with angular blocks and small fragments of limestone and stalactite; and here and there it contains beds of stalagmite. The animal remains in this deposit were those of fox, grisly bear, brown bear, badger, horse, pig, reindeer, red-deer, goat or sheep.

4. *Laminated Clay*, thin at the entrance of the cave, but thickening inwards to as much as twelve feet. It is worthy of note that glaciated or ice-scratched boulders have been found embedded in it.

5. *Lower Cave-earth*, having the same general character as the upper bed. Its mammalian remains represent the following: hyæna, fox, badger, brown bear, grisly bear, *Elephas antiquus*, *Rhinoceros leptorhinus*, hippopotamus, *Bos primigenius*, bison, goat, red-deer. One bone met with in this bed has given rise to much discussion. On its discovery it was identified by Mr. Busk as a human fibula, and had its place of sepulture been Kent's Cave, or indeed any cave but that in which it was found, perhaps Mr. Busk's identification would never have been challenged. But as its position in Victoria Cave implied, according to Mr. Tiddeman and others, the existence of man in England before what is called the Ice Age or Glacial Period, grave doubts have been thrown upon its human character; or, as Professor Ramsay remarks, "some eminent osteologists have lately declared that though they cannot assert that the fragment is not part of the bone of a man, on the other hand they cannot deny that it may just as well be part of the fibula of a bear."[1] The former presence of man, however, is apparently indicated by the discovery of certain bones which look as if they had been hacked by some instrument.

I have said that the cave-earths and intervening laminated clay occur inside the Victoria Cave, while the overlying Neolithic and Romano-Celtic layers were found just at the entrance, resting partly on the older deposits, and partly on a talus of *débris* that obscures the truncated ends of the true Pleistocene beds. When this talus of blocks and rubbish, which had fallen down from the cliff and concealed the entrance to the cave, had been cleared away, it was found to rest upon a peculiar deposit called "glacial drift," of which I shall have much to say in the sequel. From its position it was evident that this "glacial drift" was of younger date than the lower cave-earth, and was probably connected in its origin with the overlying laminated clay.

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[1] *Physical Geology and Geography of Great Britain.* 5th edition, p. 466.

The succession of changes which is evidenced by the phenomena exposed during the exploration of this interesting cave Mr. Tiddeman has shown to be as follows: First, we have the occupation of the cave by hyænas, and now and then by bears, by whose agency it is probable that most of the other bones found in the lower cave-earth were introduced; for it may fairly be inferred, from the presence of hyænas' coprolites, and the abundant osseous remains of this animal and bears, that these were actual denizens of the cave. Since doubt has been cast upon the character of the *fibula*, which was at first believed to be human, Mr. Tiddeman rejects it altogether, but the presence of the cut bones he holds to be a proof that man was a native of Yorkshire at this period. And as the bones met with in the lower cave-earth belong to species with which it has been demonstrated that man was certainly contemporaneous in many other parts of England and the Continent, it is in the highest degree probable that man did live in the north of England at the time the Victoria Cave was a den of hyænas.

The "glacial drift" and laminated clay, according to Mr. Tiddeman, prove that after the cave had been the abode of hyænas for a prolonged time, it was at last abandoned, and the valley of the Ribble was occupied by a large glacier or part of an extensive sheet of land-ice, which, creeping down the valley, deposited its morainic *débris* in front of the cave, while from the melting ice muddy water flowed into the cavern, and spread out the silt or laminated clay.[1] By and by this glacier disappeared, and then the remains of another group of animals were introduced, and gradually accumulated in what is now the upper cave-earth. This upper bed is distinguished from the lower by the marked absence of such animals as hyæna, elephant, rhinoceros, and hippopotamus, and by the presence of certain animals which are confined to it, namely horse and pig. To these species peculiar to the upper cave-earth may probably be added the reindeer, for it seems doubtful whether the remains of that animal said to have been obtained from the lower earth really belonged to that deposit. Remains of the reindeer, however, certainly occur in the upper bed. From the presence of the pig, and the absence of the more characteristic Pleistocene species that are common in the lower stratum, we seem justified in classing the upper cave-earth as of early Post-pleistocene age.

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[1] Such laminated clays are frequently found in connection with boulder-clay or "glacial drift," not only in the British Islands, but in Switzerland and Northern Italy. They represent the action of the water which is nearly always circulating underneath a glacier. The few ice-scratched stones which the laminated clays sometimes contain have been derived from the under-surface of the glacier. I have seen fine examples of these deposits at various places in the railway cuttings between Mendrisio and Balerna (Como and Lugano railway), and I have observed them also in the till of the valley of the Arve, and other places in Switzerland. They are extremely common in Scotland, and have been described by Scandinavian glacialists as being frequently met with in Sweden and Norway. They seem to be in like manner abundant in the glacial deposits of North America.

The so-called Neolithic layer is separated from the Romano-Celtic stratum by some thickness of talus, showing probably that the cave had been unoccupied by man for some considerable time before the Romanised Britons were forced to take refuge there.

The most interesting point in connection with the deposits of this cave is the evidence which shows that after the disappearance of the old Pleistocene fauna of Yorkshire—the hyænas, elephants, rhinoceroses, and hippopotamuses, with which Palæolithic man was contemporaneous—there ensued a prolonged period during which an intensely cold climate supervened, and thick glacier-ice filled the valley of the Ribble. When that ice had melted away, and the land again became fitted to support a mammalian fauna, it was not carnivores such as the hyæna, or pachyderms such as the elephant and hippopotamus, that immigrated thither, but an assemblage of animals more or less characteristic of Post-pleistocene and Neolithic times. The faunas of the two cave-earths could hardly in fact be more strongly contrasted.

The caves of Belgium, Germany, France, and other countries, have yielded, speaking generally, very much the same kind of evidence as that supplied by the cavern-deposits of England.

In certain of the river-valleys in Belgium, particularly in those of the Lesse, the Molignée, and the Samson, which are tributaries of the Meuse, a number of fine caves and rock-shelters occur. They have all proved more or less interesting to the archæologist and geologist, and the evidence they furnish as to the contemporaneity of man and the old mammalia, and the prolonged duration of the Pleistocene Period, is most complete. Of late years they have been very carefully examined by M. Dupont, director of the Royal Museum in Brussels.[1] No fewer than forty-three caverns in the valleys of the Lesse and the Molignée have been scientifically examined, and of these twenty-five have yielded traces of man. M. Dupont's conclusions, therefore, based as they are upon such a broad foundation of personal experience, could hardly fail to be both interesting and suggestive. It is a very great advantage that so many caves should have been examined by one man, because he is able to say what features of the evidence are invariable, and what may be looked upon as accidental. Thus, if such an observer shall find that certain phenomena are present in every case, he will accord to these a due importance in his endeavours to arrive at the meaning of the evidence; while an equally careful observer, whose attention had been directed to only one or two caves, and these perhaps widely separated, might likely enough fail to give needful weight to some parts of the evidence, and even miss their meaning altogether.

The caves described by M. Dupont vary considerably in size, some being large and roomy, and more or less easy of access, while others are mere narrow crevices and rock-shelters. They occur in the rocky escarpments at different levels above the streams, from a few yards up to nearly 200 feet. The floor-deposits consist generally of alternations of fluviatile sediment, with layers of stalagmite, and what we may term bone-beds. These are the more ancient accumulations, and they abound in relics and remains of the Palæolithic Period. Above the Palæolithic deposits comes a mass of yellow clay and angular stones, which is often covered with deposits of loam and brick-earth. Relics and remains of the Neolithic Age occur at and near the surface of these superficial accumulations, but are never met with in an underlying position. The yellow clay, therefore, takes its place in the series between the accumulations belonging to the Old Stone Age and those which mark the later or New Stone Period.

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[1] The descriptions given above are taken from M. Dupont's interesting volume already cited.

M. Dupont recognises two stages in the Palæolithic Period, one of which is called the Mammoth period, and the other, which is the more recent, the Reindeer period. These names are also employed by French geologists to mark similar stages in the floor-deposits of the caves in their country, but they have never met with much acceptance in England. The names indeed are unfortunate, for it is quite certain that the reindeer occupied Belgium and France in the so-called Mammoth period, and we have no reason to doubt that the mammoth lived down to the very close of the Palæolithic Age. It is quite an open question whether it did not even survive in Europe to Neolithic times. But while the mere names may be cavilled at, there can be no doubt that M. Dupont and others have brought forward evidence sufficient to show that the closing stage of the Palæolithic Period was marked by the abundance of the reindeer and other northern forms, and by the presence of the extinct species in greatly reduced numbers. The implements belonging to the so-called Reindeer period of Belgium are also indicative, upon the whole, of more advanced conditions than obtained during the earlier phases of the Palæolithic age, as these are represented in the caves of that country.

The fluviatile deposits which occupy the floors of the Belgian caves have of course been carried into them by the streams, but many of the caves are now far removed beyond the reach of even the highest floods. It is clear then, according to M. Dupont, that such caves bear witness to the gradual erosion or excavation of the valleys, and that river-deposits which occur in caves at the highest levels must be the most ancient of the

Palæolithic series. Near Montaigle, for example, there are several caves the fluviatile deposits in which must belong to very different stages. Of this group the Trou de l'Érable occurs at a level of nearly 200 feet (60 mètres) above the river Molignée, the Trous du Sureau, du Chêne, and du Lievre, are between 98 feet and 115 feet (30 and 35 mètres), while the Trou de Philippe is not more than 33 feet (10 mètres). The loam that lies in the Trou de l'Érable was introduced at a period when the river was flowing at a very high level—at least 197 feet above the present stream. In the course of time the valley was gradually deepened, and the river was no longer able to flood the Trou de l'Érable, but just succeeded in now and then reaching the caves at the lower levels. The river's bed had in fact been lowered in the interim by about 170 feet, and this of itself implies the lapse of a very long time indeed. Hence the loam in the Trou de l'Érable is justly considered to be much older than the similar deposit that forms the floor of the caves at a less elevation. Its contents show that man, mammoths, bears, hyænas, reindeer, and other animals, were even at that distant date living in Belgium; but it is in the caves at lower levels where the most numerous and interesting relics of the Palæolithic Period are found.

One of these, the Trou du Sureau (108 feet above the river Molignée), appears to have been long occupied, at successive times, as a place of abode by Palæolithic man—the successive occupations being represented by old "surfaces," or "floors," which are marked by precisely the same kind of features. Each is made up of quantities of bones, split, broken, and burnt, commingled with which are flakes and fragments of flint—the *débris* resulting from the manufacture and breakage of stone implements. Traces of fire were seen in the burnt or baked earth of the floor, and in the mixture of cinders and charcoal that appeared in the middle of the cave. The bones and implements were always most abundant in the vicinity of the old hearth.

The flint implements are of rude make, and somewhat triangular in form. They consist of a poor kind of flint, got in the neighbourhood, and show usually one plane surface, the other side being roughly chipped so as to obtain a more or less sharp edge. Along with these occurred pointed implements made of reindeer-horn, which are supposed to be javelin-heads.

The animal-remains include those of mammoth, rhinoceros, horse, common stag, urus, aurochs, reindeer, chamois, great cave-bear, grisly bear, fox, wolf, lion, hyæna. Remains of the cave-bear were most abundant.

The old floors which have yielded all this *débris* of ancient life were separated from each other by deposits of stratified loamy silt, pointing to times of flood when the river swelled above its normal level and filled the caves with muddy water, from which a deposition of fine silt took place. Three floors separated by intervening accumulations of silt and mud were observed in this cave—all of them being referred by M. Dupont to the Mammoth period. Immediately overlying these older deposits were found flint implements, with bones of the reindeer, horse, wild-boar, roebuck, goat,[1] badger, fox, dog, and hare. This accumulation is assigned to the Reindeer period. The bones were scattered about the floor of the cave,[2] and were covered over by an accumulation of yellow clay containing many stones and blocks.

Above the yellow clay comes a loose *débris* of stones which have tumbled and rolled down from time to time. Amongst these have been detected polished stone implements and fragments of pottery, along with the bones of ox and badger. The same is the case in another cave, the Trou du Chêne, where a mass of yellow clay with stones separates the deposits of Palæolithic age from those that contain the relics of Neolithic and more modern times. In the Trou de Pont-à-Lesse (which is a mere shallow rock-shelter, situated some little distance from the Trou Magrite, to be described in the following chapter) the same yellow clay with stones is found. It is overlaid with a loose superficial *débris* of fallen stones, amongst which occur two bone-beds containing human bones and relics, which are referred by M. Dupont to the Neolithic Age.

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[1] The goat is frequently mentioned by Dupont as occurring in the caves of Belgium. Other osteologists have doubted this determination—the goat never having been obtained in the Pleistocene deposits of France or England. Mr. Tiddeman, however, records it from the lower cave-earth of Victoria Cave, Yorkshire, in close proximity to *Elephas antiquus*.

[2] At one place opposite the principal entrance to the cave occurred a heap of bones belonging to several small mammifers, birds, batrachians, and freshwater fish. These M. Dupont also assigns to the Reindeer period, and the presence of lemming, lagomys, and Arctic fox seems in favour of this view. Many of the other bones belong to burrowing species, such as mole, field-rat, field-mouse, etc. There is some difficulty in accounting for such a miscellaneous collection. No flint implements and no remains of those animals which formed the food of the folk who occupied the Trou du Sureau in Palæolithic times, occur in the heap, which therefore probably does not owe its origin to man.

CHAPTER VII.

CAVE-DEPOSITS OF THE PLEISTOCENE PERIOD—*Continued.*

Bone-caves of Belgium—The Trou Magrite—Contrast between lower and upper deposits—Trou de la Naulette—Human bones associated with remains of extinct animals—The Cavern of Goyet—The Trou du Frontal—Age of sepulchral cavity—Caves of Germany and France—General conclusions as to caves—Evidence of progress during Palæolithic Period—Reindeer period in Belgium and France—Cold climatic conditions during the closing stage of Palæolithic Period—Alternations of genial and cold climates in earlier stages of same period—Break between Palæolithic and Neolithic Ages.

In the valley of the Lesse, nearly all the caves occur towards the middle of the escarpment at a height of between 65 feet and 115 feet (20 and 35 mètres) above the river. One of the most important is the Trou Magrite at Pont-à-Lesse. The deposits in this cave consist of a basement-bed, eight feet thick, of gravel and water-worn stones, over which comes the usual stratified silt, containing intercalated with it four distinct layers of broken bones, which evidently represent the *débris* or refuse strewed over the floor at so many successive periods when the cave was tenanted by man. The stratified silt that separates one refuse-heap from another indicates, on the other hand, the occurrence of so many inundations by which the human occupation of the cave was interrupted.

There are some remarkable differences between the lower and upper "floors." In the former, remains of the extinct animals are very numerous, while in the latter they are less so, those floors being characterised by the abundance of bones o reindeer and horse. Again, the stone implements in the lowe levels are analogous to those found at Montaigle; they are rudely shaped and finished, and half-finished specimens occur in large numbers. Many of these spoiled implements are made of the black marble of the district—the others are of flint. Points or arrow-heads fashioned of reindeer's horn are also met with. The implements got in the upper bone-beds or "floors" are not of the rude form and finish of the Montaigle type, but consist of long well-shaped flakes of flint (so-called "knives"). Others again are furnished with a "peduncle," as if they were meant to be sunk into a shaft of wood and used for spearing purposes. Their workmanship indicates decidedly more skill than that of the implements obtained from the lower levels in the same cave. But the most remarkable "finds" in the upper floors consist of portions of reindeer's horn showing etchings or engravings, which have been traced by some sharp point—no doubt, by a flint implement. One small bit of horn has been cut or scraped so as to present the rude outline of a human figure.

Another of the more interesting caves that occur in the valley of the Lesse is the Trou de la Naulette, which has been occupied at separate times by men and wild beasts. The entrance to this cave is about 90 feet above the level of the river. The floor is covered with 36 feet of fluviatile silt—the lower portion of which was deposited at a time when the Lesse flowed at the level of the entrance, while the upper portion consists of flood-accumulations carried into the cave at a time when the river at its normal level had ceased to reach the entrance. These flood-accumulations consist of seven separate beds or layers which are separated by an equal number of stalagmitic pavements. The latter of course indicate periods of more or less duration during which there were no inundations, and the cave remained dry. Bones are met with above the first, second, and seventh stalagmitic floors. Those of the first layer indicate that the cave was at that time a hyæna's den, which is proved by the presence of remains of that animal together with abundance of gnawed bones of various ruminants. The second bone-bed affords evidence that during its accumulation the Trou de la Naulette was the abode of Palæolithic man. This is shown by the heaps of bones which have been split longitudinally for the sake of the marrow—many of them showing the marks of blows made doubtless with stone implements. Besides these were found a human lower jaw and other bones. The animal remains associated with them indicate a group of animals characteristically Pleistocene. Among these were mammoth, rhinoceros, horse, wild-boar, small-ox, goat, chamois, reindeer, common stag, roebuck, marmot, squirrel, mole, water-rat, hare, brown bear, pole-cat, wolf, fox, dog, wild-cat, and some birds, batrachians, and freshwater fish.

The Pleistocene deposits are overlaid as usual with an accumulation of yellow clay charged with angular stones.

The cavern of Goyet occurs in the valley of the Samson, another tributary of the Meuse, at a height of about 50 feet above the level of the stream. It contains five bone-layers alternating with six beds of alluvial deposits. The fifth or lowest level contained remains of the lion commingled with those of the cave-bear which occurred in great abundance. The fourth level indicated that during the time it formed the floor hyænas and bears occupied the cave. The bones of their prey were those of man, lynx, pole-cat, wolf, fox, rhinoceros, mammoth, horse, chamois, wapiti, the great Irish deer, reindeer, and ox. Remains of the lion, hyæna, and cave-bear occurred in great abundance, and the evidence showed that these animals had occupied the cave at successive periods. During the accumulations of the fifth bone-bed it would appear that the lion was the first occupant, and that he was succeeded by the bear. In like manner during the formation of the fourth bone-bed the cave was first a hyæna's den and afterwards became the haunt of bears. The third floor was occupied by Palæolithic hunters, the relics of whose feasts occur in abundance. The flint implements are of the primitive type found at Montaigle. The animal remains of this level belong to the following species—cave-bear, brown bear, badger, weasel or ermine, dog, wolf, common fox, blue fox, hyæna, lion, hare, marmot, rhinoceros, mammoth, horse, goat, chamois, bouquetin, stag, roebuck, reindeer, ox, urus, and some birds. Human bones were found among the others. In the second layer occurred flint implements approaching in form the types found at Montaigle and in the Trou Magrite. Besides these were a number of implements and carved and ornamented objects formed of reindeer's horn, resembling those discovered by MM. Larty and Christy in the caverns of Périgord. The animal remains of this level belonged to cave-bear, badger, wolf, common fox, blue fox, hyæna, lion, hare, rhinoceros, mammoth, horse, wild-boar, goat, chamois, stag, reindeer, ox, and birds. The first or highest level was rich in human relics in flint and horn, which evinced better workmanship than the similar relics found in the other caverns. The flint implements consisted principally of well-shaped blades and flakes; and there were numerous bodkins or awls, javelin- or arrow-heads, and harpoons in bone and horn, besides teeth of wolf, fox, stag, horse, and ox, which were drilled, as if for the purpose of being suspended by way of ornament. The species whose remains are met with in this upper level consist of cave-bear, brown bear, polecat, wolf, common fox, blue fox, hyæna, rhinoceros, mammoth, horse, wild-boar, hare, goat, chamois, stag, reindeer, ox, and various birds. A few human bones were also found.

I shall refer to only another Belgian cave—the Trou du Frontal, which occurs in the valley of the Lesse, near the village of Furfooz. M. Dupont gives a section of this cave, which is here reproduced (Fig. 3). The lowest deposits consist of clay (4), over which come beds of gravel (3) and alluvial silt (2). These represent, of course, the older accumulations of the river. At H H were found many broken bones belonging to lemming, reindeer, lagomys, stag, urus, beaver, chamois, horse, and other animals; and at F burnt bones and charcoal indicated an old hearth. A number of human skeletons occurred in what appears to have been a sepulchral cavity (S), the entrance to which had been closed by a slab of stone (D). At the entrance to the cavity was found an urn, along with flint implements, perforated shells, and a piece of fluorine, which was likewise perforated, and had doubtless been used as an ornament. The human remains were confusedly mingled with clay and angular stones, and a mass of the same materials (1) covered over the old hearth and the bone-*debris* (H H), and extended down the slope of the hill so as to dip underneath the modern alluvium of the Lesse. The bone-*débris* and the hearth must have been in existence before the stony clay began to accumulate, and M. Dupont has no doubt that the human skeletons are likewise of older date than that superficial covering. Indeed, he does not hesitate to connect the bone-*débris* at H H with the human remains in the sepulchral cavity, and is of opinion that the former are the relics of the feasts which took place at the burials. In this, however, he may be mistaken, and, as Professor Boyd Dawkins has pointed out, the burial-place may have belonged to one people, and the refuse-heaps outside the slab to another. We may suppose that the cavity was in use for a burial-place after the clay with stones had accumulated, and

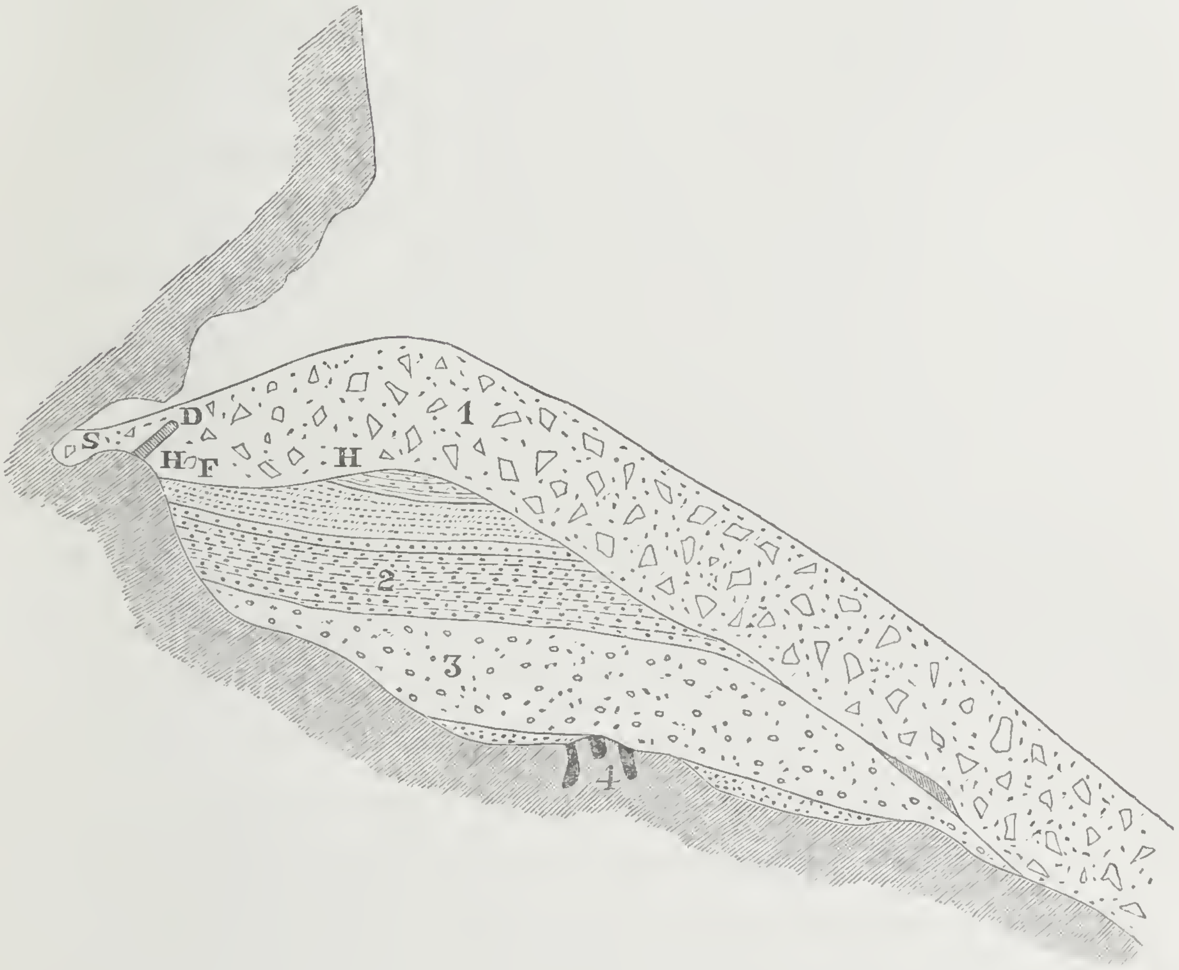

Fig. 3.—Section of Deposits in the Trou du Frontal. (Dupont.)

that therefore it may belong to a much later date than the Palæolithic refuse-heaps at H H. Another objection to this sepulchral cavity with its contents being of Palæolithic Age is the character of the human remains and relics. "The form of the urn," as Mr. Dawkins says, "is remarkably like some of those which have been obtained from the Neolithic pile-dwellings of Switzerland, and therefore may possibly imply that the interment is of that age." The skulls also "seem to be of the same general order as the broad skulls from the Neolithic caves and tombs of France, and from the round barrows of Great Britain, as well as those from the Neolithic tombs of Borreby and Möen in Scandinavia."

From the foregoing descriptions of English and Belgian caves, the reader will gather a fair notion of the kind of evidence that Palæolithic cavern-deposits usually supply. A description of the cave-accumulations of France, Switzerland, and Germany would, in large measure, be a repetition of the same tale. It is not necessary for my purpose to do more than merely indicate the general gist of the evidence, and this may be done very briefly. The caves and rock-shelters which we have already passed in review contain, as we have seen, relics pertaining to different stages of the Palæolithic Period. The same holds true with the caves of France and other countries. French archæologists, indeed, have classified their caverns according to what they conceive is the relative antiquity of the relics and remains which they contain. In the oldest series are included those caves which have yielded remains of the cave-bear in greatest plenty, and in which the human relics of rudest form and finish occur; while the newer series comprises those caverns in which remains of the reindeer are most abundant, and where the human implements evince the greatest skill and perfection of workmanship. Among the former come such caves as that of Vallières (Loir-et-Cher), discovered by M. de Vibraye, which contains bones of rhinoceros, hyæna, megaceros, urus, horse, etc., along with flint implements of the rudest types. Another example is that of the Grotte des Fées at

Arcy-sur-cure (Yonne), in which M. de Vibraye discovered bones of mammoth, cave-bear, rhinoceros, and hyæna, with rude flint implements and a human vertebra. In the cavern of Pontit (Herault), the lower deposits contained remains of rhinoceros, cave-bear, urus, etc., while in the upper layers were charcoal and implements of flint, bone, and horn, commingled with bones of horse, urus, etc. The uppermost layer was of Neolithic Age, and yielded polished stone implements, pottery, etc. But one of the most interesting caves is that of Moustier (Périgord), described by MM. Lartet and Christy. It has yielded remains of hyæna, cave-bear, and mammoth, with flint implements which approach in character to those discovered at Vallières, and in certain ancient river-gravels at Abbeville, which will be referred to in the following chapter. The caverns and stations belonging to the later stage of the Palæolithic Period, or so-called Reindeer epoch, are the most abundant in France. They are especially numerous in the steep rocky banks and cliffs of the valleys of the Dordogne and the Vezère in Périgord, where they have been studied by the late MM. Lartet and Christy, who have furnished us with many most interesting details of the conditions that obtained during the closing scenes of Palæolithic times. From the caves of Périgord and some of those in the Pyrenees have come the most numerous and best finished examples of carved and engraved horns, and bones and ivory.[1] The character of these and other human relics, and the fact that they are invariably associated with plentiful remains of the reindeer, show that the caves of Périgord and the lower valleys of the Pyrenees were occupied towards the close of the Palæolithic Period by a race of hunters and fishers who lived under cold climatic conditions; and the close analogy presented by these French caves to those of Belgium renders it in the highest degree probable that both belong approximately to the same age. Among the more important French caves and stations of this age are those of Massat (Ariége), La Vache, near Tarascon (Ariége), Bruniquel, on the borders of Aveyron (Tarn-et-Garonne),

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[1] Fine engravings have also been discovered in the Kesserloch, a Swiss cave.

Eyzies, near Tayac (Périgord), Laugerie (Périgord), La Madeleine (Périgord), Gourdan (Haute-Garonne), Duruthy (Pyrenées), Sartenette and La Salpétrière in the lower valley of Gardon, etc.

Although these caves are said to belong to the Reindeer period, it must not be supposed that the caves pertaining to the so-called epoch of the Cave-bear and the Mammoth contain no traces of the northern fauna. On the contrary, even those caves which are assigned by archæologists to the earliest stages of Palæolithic times often contain representatives from the northern, southern, and temperate groups. But in the older caves remains of the extinct forms predominate—such as cave-bear, mammoth, rhinoceros, etc.—while the reindeer and its immediate associates are less frequently met with. In the caves of the so-called Reindeer period, the extinct forms are less numerous, and the reindeer, on the contrary, very abundant.

The caves of Germany and Switzerland have likewise supplied us with plentiful remains of the mammalian fauna of Palæolithic times. Among the best known are those of Gailenruth and Muggendorf in the valley of the Wiesent; Baumannshöhle, Bielshöhle, and others in the Harz; and those which occur in the limestone-districts of Westphalia between Düsseldorf and Iserlohn. They are not uncommon in the northern part of the Jura Mountains (Franconian Alb), and they occur now and again in the same hilly tract between Schaffhausen and Coburg. The Kesserloch near Thäingen, in the canton of Schaffhausen, and the cave of Veyrier, near Geneva, are famous Swiss caves in which relics of the Reindeer period occur in great abundance.

The caves of Southern Europe are also rich in animal *débris,* but they differ from those of Central Europe in never having yielded remains of the reindeer or the musk-sheep. So far as we yet know, neither of these animals ever went south of the Pyrenees and the Alps. Certain other species, however, which are now confined to high latitudes or alpine elevations, appear at one time to have lived at low levels in the Mediterranean regions. Thus M. Rivière has discovered the remains of the glutton in caves near Mentone,[1] and a lagomys or tailless hare is not uncommon in the breccias of Corsica and Sardinia.[2] The marmot, which is now confined in the Alps nearly to the borders of perpetual snow, formerly lived, according to Gastaldi, at the foot of the southern slopes of the Moncalieri-Valenza hills, where its remains have been met with on several occasions.[3] The mammoth also at the same time frequented Spain and Central Italy. But the general facies of the mammalian fauna in the ossiferous deposits of Southern Europe is, as we might have expected, rather southern than northern. We miss the reindeer and the musk-sheep, and at the same time encounter certain animals of southern habitat which are either wanting or very rare in the cave-accumulations of North-western Europe. It must be noted, however, that animals which are more or less characteristic of a temperate climate are plentiful. Red-deer, roe, fallow-deer, ibex, urus, horse, wild-boar, rabbit, cave-bear, brown bear, grisly bear, wolf, fox, etc., were associated in the same region with lion, leopard, lynx, Caffer-cat, serval, hyæna, rhinoceros (*Rh. hemitœchus*), elephant (*E. antiquus* and *africanus*), hippopotamus (*H. major* and *Pentlandi*), etc. Although there is nothing, therefore, in the evidence furnished by the caves and breccias of the south that would lead us to infer that the Mediterranean region was ever subject to conditions as cold as those which obtained in Southern France during the Reindeer period, yet we are not without indications of a less genial climate than the present having formerly prevailed. The presence at low levels in Italy of such animals as tailless hares and marmots, and the occurrence of the glutton at Mentone and the mammoth in Spain and Italy, is in perfect harmony with the appearance of a northern fauna in Southern France.

The more noted caves, etc., of Southern Europe are those of

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[1] *Compt. Rend. Assoc. Franç. pour l'Avance. des Sciences*, Paris, 1878, p. 622; *Bull. Soc. Géol. France*, 3ᵉ Sér. t. vi. p. 621.

[2] Locard: *Archiv. du Mus. d'Hist. Nat. de Lyon*, 1873.

[3] "Intorno ad alcuni resti fossili di *Arctomys* e di *Ursus spelæus*," *Atti R. Accad. Scienze, Torino*, 1871.

Gibraltar, Provence, Mentone, Sicily, and Malta. The Sicilian caves abound in remains of the pigmy hippopotamus, which occurs also very plentifully in the Maltese caves,[1] where it is associated with species of dwarf or pigmy elephant. Remains of the pigmy hippopotamus have not until recently been obtained *in situ* on the mainland of Europe. Professor Capellini, however, now records them from the cave of Santa Teresa, near Spezia.[2] Human remains and relics and traces of man's presence occur in various caves in Southern Europe, and there can be no doubt that the ossiferous deposits in those caves are of the same age as the similar accumulations in Central and North-western Europe.

The facts now briefly passed in review enable us to arrive at certain conclusions which it may be well to sum up before we turn to the next stage in our inquiry. I have already dwelt with sufficient emphasis on the great antiquity of the cave-deposits. This is proved by a variety of considerations, such as the thickness of the stalagmitic pavements, the very considerable changes which were effected in the drainage-systems during the course of the Palæolithic Period, the great depth to which many valleys were eroded by their streams, so that caves which in early Pleistocene times were liable to constant or intermittent flooding became by and by quite dry, the streams, even when most swollen, being unable any longer to reach the openings into the caverns. Such are some of the more evident proofs of the antiquity of the Old Stone Age. But the changes of climate and physical conditions to which the mammalia bear witness are not less eloquent of the prolonged duration of that remarkable epoch. To whatever cause those climatic mutations may have been due, we cannot believe that they came upon our continent all of a sudden, and then passed as rapidly away. Such great changes are only brought about very gradually, and therefore they necessarily imply a long lapse of time. But, leaving these and other general considerations for the present, I would merely recapitulate a few points which seem to be of special importance.

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[1] The Maltese breccias are referred to more particularly in Chapter XIII.

[2] *Mem. dell' Accad. delle Scienze dell' Istituto di Bologna*, Ser. 3. tom. x. 1879.

The first of these is the fact that in many bone-caves of Palæolithic age, the upper deposits contain relics which evince more skill, and, upon the whole, a greater degree of advance than those that are common in the lower accumulations. Are we to believe that we have, in this case, proofs of a gradual advance in the same people from a very low state of savagery to a less barbarous condition? Or may the difference between the implements of the lower and upper deposits simply show that one tribe was dispossessed by another coming later in time into Western Europe? Again, have we any reason to believe that the cave-deposits of the so-called Reindeer period are, in all cases, of later date than those cave-accumulations which contain more abundant remains of the extinct species, and which are assigned by some archæologists to what is called the Mammoth period? May not it be that one set of caves was inhabited contemporaneously with the other; in other words, may not the men who fashioned the rudest flint implements have lived at the same time as the artistic tribes of the Dordogne and other places? I have already quoted some remarks made by Professor Dawkins to the effect that any attempt to classify cave-deposits according to the relative rudeness of their implements cannot be relied upon, because "the difference may have been due to different tribes or families having co-existed without intercourse with each other." And the same osteologist has pointed out that the northern, southern, and temperate species of mammalia are so associated together in the Pleistocene deposits of Europe, that no classification can be founded upon the relative predominance or scarcity of any particular species in the caves. "The difference," says Professor Dawkins, "between the contents of one Palæolithic cave and another, is probably largely due to the fact that man could more easily catch some animals than others, as well as to the preference for one kind of food before another. And the abundance of the reindeer, which is supposed to characterise the Reindeer period, may reasonably be accounted for by the fact that it would be more easily captured by a savage hunter than the mammoth, woolly rhinoceros, cave-bear, lion, or hyæna."[1]

There is much force in these remarks, and one cannot but feel that the considerations urged by Professor Dawkins would be to a great extent unanswerable if the relative antiquity of cave-deposits were to be decided solely by an appeal to the evidence which he calls in question. But when we discover, in such caves as contain a succession of several deposits, that the higher beds are frequently charged with human relics of better finish and more varied design than those of the lower strata, while the reverse appears never to occur, we cannot in such cases admit that his objections have much weight. We have seen that in Kent's Cave the implements obtained from the lower stages were of a much ruder description than the various objects detected in the upper cave-earth and the black-band. And a very long time must have elapsed between the formation of the lower and upper Palæolithic beds in that cave. Precisely the same phenomena are met with in several of the bone-caves in Belgium and France, and the conclusion is forced upon us that in these particular cases the caves were tenanted in late Palæolithic times by tribes considerably farther advanced than the savages who occupied them at an earlier date. Whether the latest Palæolithic tribes were the same race as the latter, who in the course of the ages had gradually attained a somewhat more advanced stage; or whether, as there is some reason for thinking, they may have been immigrants from some other region who dispossessed the older inhabitants, we cannot yet say, but future discoveries will probably decide.

Again, it may well be admitted that the mere abundance of the reindeer in the deposits of the so-called Reindeer period is no proof that the extinct mammalia such as mammoths, woolly rhinoceroses, and so forth, were not living in great numbers during that period. No doubt all those animals that were capable of occupying the same feeding-grounds as the reindeer, might be as abundant in late Pleistocene times as they ever were at any earlier period. But when we find that the true southern species — the hippopotamus, the elephant, and the rhinoceros—are conspicuous by their absence from the deposits of late Palæolithic times, it seems more reasonable to suppose that their absence was due rather to changed climatic conditions than to any difficulty the old savages might have had in capturing them. All the evidence conspires to show that towards the close of the Old Stone Age the climate of Europe was cold and arctic, so that animals which are now met with only in northern regions, or at high altitudes in alpine districts, occupied the low grounds as far south as Périgord in France. The folk of that closing period lived very much in the same way as the Eskimo live now, fishing in the cold waters and hunting in the "barren grounds;" the refuse of their feasts was allowed to accumulate on the floor of their dwelling-places, and they probably suffered no more inconvenience from the presence of the unsavoury heaps than similarly-circumstanced tribes in our own day. We can picture them to ourselves feasting round their fires on reindeer-flesh, or splitting up the bones and sucking the juicy marrow. At other times, when perhaps reindeer-hunting had proved unsuccessful, they were content to catch such fish as they could in the rivers, or to capture lemmings, weasels, water-rats, and other small animals, and birds. Their tastes do not seem to have been very eclectic, and from the relics of their feasts we gather a pretty fair idea of the mammalian fauna of the lands they lived in. But, as we have seen, they seem to have had no domestic animals, nor have we any reason to believe that they knew anything of agriculture. The potter's art appears likewise to have been unknown. The most distinguishing characteristic of the reindeer-hunters, however, was their love of art, a characteristic which, as we know from the analogy of the living Eskimo, may co-exist with a very low state of civilisation.

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[1] *Cave-hunting*, p. 352.

In the earlier stages of the Palæolithic Period we have proof in the commingled remains of animals that belong to widely-separated zones of considerable changes of climate. Cold and genial conditions had alternated long before the time when the caves of Périgord were tenanted by the artistic reindeer-hunter; for plentiful remains of northern, temperate, and southern species occur in deposits, that go back to much earlier dates. Whether we shall ever be able, from a study of the bone-caves alone, to discover how many such changes took place during the Old Stone Age, is extremely doubtful; we might even say, highly improbable. But there are various collateral lines of evidence, which, if followed up, will, I believe, greatly aid us in our endeavours, and eventually help us to decipher much that is at present enigmatical and obscure.

Not only do the cave-deposits bear witness to past vicissitudes of climate—to changes in the relative position of land and sea,—to considerable modifications in the physical features of our river-valleys—and to the prolonged duration of that period during which man was contemporaneous with the extinct or no longer indigenous mammalia,—but they also testify to the remarkable fact that the Old Stone Age did not graduate as it were into the New Stone Age. The records of the latter epoch are separated very markedly from those of the former. No sooner do we pass from the uppermost deposits of Pleistocene age to the more modern accumulations, than all at once we find ourselves in quite another world. The hyænas and lions, the rhinoceroses and mammoths, have disappeared, and we are now face to face with a group of animals that we recognise as being the common indigenous European forms of our own day. Palæolithic man has likewise vanished, and his place is supplied by races considerably farther advanced on the road to civilisation. Neolithic man was not only a hunter and fisher like his predecessors, but he possessed some knowledge of agriculture, and of the arts of weaving and making pottery. His implements show more variety of design and are upon the whole much better finished, being frequently ground at the edges, and often smoothed and polished. He was also accompanied by domesticated animals, and in some cases occupied well-constructed houses, which doubtless for security's sake were built in lakes ; and in many other respects he was decidedly in advance even of the artistic hunters of the Reindeer period.

The geological position in which the relics of Neolithic times are found, bears emphatic testimony to the lapse of time that separates the close of the Old Stone Age in Europe from the beginning of the succeeding New Stone or Neolithic Period. The implements belonging to the latter epoch occupy invariably a superficial position—they occur either lying loosely at the surface or embedded at no great depth, in accumulations which can be shown to be of very recent date, geologically speaking. In undisturbed cave-deposits they are never commingled with the relics of the older period, but are not infrequently separated from these by sheets of stalagmite, accumulations of earth and *débris*, or beds of clay, silt, sand, gravel, and other materials. Several good examples of this character have already been given. Thus in Kent's Cave we have seen that the archaic and more modern remains rested upon a bed of granular stalagmite, in and underneath which only did Palæolithic implements and the bones of the extinct mammalia occur. All these had been sealed up and the cave had been long abandoned before it was again tenanted by man. In the interim many large and small blocks had fallen from the roof and accumulated upon the floor. Again, after the cave at Brixham had been for a long time open to the visits of Palæolithic man and of hyænas and other animals of the period, it was finally deserted, and an accumulation of stones, dislodged by the action of the weather, gradually blocked up the entrance, so that the cave was never subsequently tenanted by man. But the evidence supplied by the Victoria Cave at Settle is still more remarkable, for we there discover that after the land had been for a long time occupied by hyænas, elephants, hippopotamuses, and other animals, a cold climate supervened, and a great glacier crept down the valley of the Ribble ; and it was not till long after that glacier had melted away that Neolithic man entered Yorkshire.

The Belgian caves in like manner afford abundant proof of the break or hiatus that divides in Europe the Palæolithic from the Neolithic Age. M. Dupont has brought forward copious evidence to show that a mass of yellow clay, more or less plentifully charged with large and small angular stones, separates the newest deposits of the Reindeer period from the Neolithic accumulations. This clay with stones, he says, is widely spread over the country, and he is inclined to attribute its formation to the action of a great *débâcle* or flood. Others again have suggested that it may owe its origin simply to the long-continued action of the weather. In whatever manner it was formed it undoubtedly indicates a period of longer or shorter duration. The Reindeer epoch came to a close, and, thereafter, the clay and stones began to accumulate, and the accumulation had apparently come to a close before Neolithic man appeared upon the scene, for his relics are now found resting either upon the surface of the clay or in the *débris* of loose stones that has subsequently gathered above it.

Did space permit, reference might be made to other examples of caves, especially in Southern France, where the evidence of a distinct separation between Palæolithic and Neolithic times is more or less strongly pronounced. But those now given may suffice, more especially as I shall presently bring forward copious collateral proofs which have been furnished by certain river-deposits, both in this country and the Continent. Meanwhile, such evidence as we have glanced at puts it beyond doubt that a considerable interval of time must have supervened after the departure of Palæolithic man and before the arrival of his Neolithic successor.

CHAPTER VIII.

RIVER-DEPOSITS OF THE PLEISTOCENE PERIOD.

M. Boucher de Perthes' discoveries—Professor Prestwich on origin of the ossiferous and implement-bearing "drifts"—Fluviatile origin of the so-called "drift"—Erosion of river valleys during Pleistocene times—Time required for excavation of valleys—Professor A. Geikie on modern denudation—Flooded condition of Pleistocene rivers—Professor Prestwich on relation between ancient river-gravels and loams—Absence of well-marked river-terraces accounted for—River ice and ice-floated erratics—Professor Prestwich on climatic conditions implied by Pleistocene river-deposits—Commingling of different groups of mammals—Sir C. Lyell's views—Mr. Darwin on angular gravels of Southern England.

THE evidence we are now about to consider is in certain respects more satisfactory than that derived from the study of cave-deposits. The latter, indeed, teach us in the most impressive manner that the Palæolithic Age is separated from our own by a great interval of time—an interval that may well be measured by hundreds of centuries; but taken by themselves alone they do not tell us to what particular stage in the geological record they ought to be referred. We have seen that their fossil contents have enabled geologists to class them as of Pleistocene age. But the term Pleistocene embraces a great variety of accumulations of diverse formation. Besides cave-deposits, there are lacustrine, fluviatile, and marine strata, some of which attain a considerable thickness, and spread over wide tracts of country. Again, there are enormous sheets and heaps of glacial detritus that cover a large part of the British Islands and Northern Europe, and gather abundantly upon the low grounds that sweep out from the base of every mountainous or alpine region in our continent. All these varied deposits and accumulations are referred by geologists to the Pleistocene Period, and it is clearly a matter of importance to discover, if we can, to what particular stage of that period the ossiferous layers of our caves belong. Must we relegate them to the beginning, the middle, or the end of Pleistocene times? What relation do they bear to the so-called Glacial Period or Ice Age? The only instance in which we find cave-deposits brought into actual contact with accumulations which are undeniably of glacial origin is that of the Victoria Cave, in Yorkshire. In that cave we have evidence to show that a cold climate, characterised by the presence of large glaciers in the north of England, supervened after the departure of hyænas, elephants, and their congeners. Does it follow, then, that all similar cave-accumulations in which the remains of these animals occur must belong to the same age as those of the Victoria Cave, or may not some be of earlier and others of later date?

It is clear that the caves themselves can give us no decisive reply to all these questions; they yield us no direct information as to the climatic and geographical conditions that obtained in Europe before the introduction and formation of their earths, silts, breccias, and stalagmites.[1] We have seen, however, that some caves certainly contain deposits of more recent Pleistocene age than others, and that the closing stage of the Palæolithic Epoch was characterised by an extremely cold climate. But we have still to learn what exact relation our cave-deposits as a whole bear to the Pleistocene Period. In a word, we have to ascertain whether the so-called Old Stone Age belongs to Preglacial, Glacial, or Postglacial times.

Fortunately for geologists, the links in the evidence which the caves fail to supply have been discovered elsewhere. In England and the Continent the fauna so characteristic of the older cave-accumulations has left its remains in certain superficial deposits of loam, sand, and gravel, the relations of which, both to older and younger geological formations, can be more or less distinctly traced. And along with these osseous remains have been found immense numbers of worked flints of the same general character as those which occur in our caves. We must now for a little glance at the evidence of the ancient deposits in which these remarkable relics of primeval times lie entombed.

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[1] This is generally true, according to our present knowledge; but there are exceptional cases, such as the caves of Gibraltar, in which the relation of the bone-bearing beds to deposits pertaining to the Glacial Period is clearly shown. See Chapter XIII.

It is to M. Boucher de Perthes of Abbeville that the honour must be assigned of having been the first to direct the attention of scientific men to the occurrence of worked flints along with bones of extinct animals in beds of undisturbed sand and gravel.[1] His discoveries, however, were for long years neglected both by French and English geologists; and it was not until after the exploration of Brixham Cave had overturned our preconceived notions of the antiquity of man, and his contemporaneity with the extinct animals, that the investigations of the Abbeville antiquarian began to attract notice. Perhaps one of the reasons why the French discoveries were so long passed over by English scientific men was the general conclusion arrived at by Boucher de Perthes, that the flint implements and mammalian remains were entombed together by the waters of the Noachian deluge. By geologists in this country the idea of a general deluge had long been discredited; and so deeply had uniformitarian doctrines been imbibed, that *débâcles* and deluges of any kind had come to be looked upon with considerable disfavour. It could be shown that the slow, continuous action of frost and rain and running-water was capable in time of effecting enormous changes on the surface of the globe; and it was considered unphilosophical to call in the agency of such accidents as *débâcles* and deluges to account for appearances which could be well explained without their aid. When an author, therefore, seemed to ignore the common agents of change, and to rely chiefly upon the supposed occurrence of a tumultuous rush of waters in his endeavours to decipher the meaning of certain geological phenomena, it is perhaps not surprising that problem and solution alike failed to attract attention. Be that, however, as it may, it is unquestionably true that the chief reason for our neglect of the evidence of man's antiquity lay in the simple fact that we were prejudiced against it. It was against their wills that most geologists were at last convinced, and numerous were the objections raised before the majority could divest themselves of their old persuasion, and accept the new views. But so cogent and abundant has the evidence now become, that the sole noncontents who venture to appear in print are writers who have merely a certain literary acquaintance with the subject, and whose objections often are, in a certain sense at least, unanswerable.

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[1] So far back as 1797, however, an English antiquarian, Mr. John Frere, had described the occurrence of flint "weapons of war" and some "extraordinary bones" in undisturbed strata of gravel and sand at Hoxne, in Suffolk. *Archæologia*, vol. xiii. p. 204. Mr. Frere's interesting letter is given *in extenso* by Mr. Prestwich in the "Author's Copies" of his famous paper, read to the Royal Society in 1859. *Philosophical Transactions*, Part II., 1860, p. 277.

It was Mr. Prestwich who some twenty years ago first drew the attention of English geologists to the discoveries made by Boucher de Perthes, and so admirably did he expound the phenomena that his conclusions at once made a profound impression. He completed a careful examination of many localities in the north of France and the south-east of England, and proved to demonstration that the flint implements were undoubtedly the work of man's hand, and had been buried in sediment contemporaneously with the remains of the Old Pleistocene mammalia. He showed, moreover, that the sand and gravel in which these relics lay entombed were not the result of any sudden *débâcle* or deluge, but had been formed and deposited by streams and rivers in the process of excavating their valleys. He pointed out, moreover, that some of the sediments spoke to the former occurrence of intermittent or periodical floods of vast extent. In short, he interpreted the phenomena on uniformitarian principles, and so clearly and cautiously did he reason out his conclusions, that his views have deservedly met with very general acceptance. They were adopted by Sir Charles Lyell in his well-known work *The*

Antiquity of Man, and the example of this eminent geologist was of course soon followed by the greater number of his disciples. Extended observations and the evidence obtained during collateral inquiries have only tended to confirm the general truth of Professor Prestwich's conclusions. My limits will not allow me, however, to give a detailed account of those investigations, which may be said to have revolutionised Pleistocene geology. All I can do is to sketch in outline the main features of the evidence, and to note the chief results arrived at.

The occurrence of great sheets of gravel, loam, and sand on the slopes of many valleys in the south of England and the north of France had long been known to geologists, and many were the explanations, advanced from time to time, to account for their presence. Few could believe that such water-worn materials—often appearing at heights of more than 100 feet above the valley-bottom—could have resulted from the action of the present streams and rivers. It was thought possible that this might well be the origin of the gravel and sand at low levels, but the more elevated deposits were assigned sometimes to the action of the sea, during a comparatively recent period of submergence, and at other times they were supposed to be due to the sweep of great cataclysmic rushes of water. Considerable doubt also existed as to the age of the gravels in different valleys, and even of those in one and the same valley. This uncertainty arose chiefly from the nature of the palæontological evidence—the fossils appearing to indicate various ages. Thus, for example, it was thought that the deposits at Brentford, in the valley of the Thames, were newer than those of Grays. Professor Prestwich, however, had on physical grounds long been satisfied of the contemporaneity of these deposits, and contended for their posteriority to the "Boulder Clay." In other words, he had come to the conclusion that they were posterior in date to the Glacial Period or Ice Age. This latter point I will not now consider, as it falls to be discussed in succeeding chapters. For the present we are concerned simply with the origin of the valley-gravels—high- and low-level deposits alike. These, Professor Prestwich was the first to show, all belong to one series, and the wide-spread "löss" or loam and brick-earth, he likewise included as part of the same phenomena.

An exhaustive examination of the gravels and loams in a number of the valleys in the north of France and the south of England enabled this geologist to demonstrate that they had been formed by river-action. This was shown by the pebbles themselves, all of which had been derived from the strata in which the valleys are excavated. Not only so, but they had also travelled in the same direction as the present streams. The fluviatile origin of the gravels in question was still farther proved by the notable fact that land- and freshwater-shells were often met with in high- and low-level deposits alike, while marine remains, save in the immediate neighbourhood of the sea, were entirely wanting.

From these old "river-drifts" flint implements of undeniable human workmanship have been obtained in large numbers, and associated with them, in the same undisturbed strata of sand and gravel, numerous remains of the Pleistocene mammalia have been found. The observations of Boucher de Perthes have thus been verified by Professor Prestwich, as also by many French and English geologists. There can be no doubt, therefore, that man and his congeners, the extinct and no longer indigenous mammalia, were in joint occupation of France and Southern England during the deposition of the ancient valley-deposits whose origin we are now considering.

One of the most remarkable characteristics of these gravel- and loam-beds is the height they frequently attain above the present levels reached by the streams and rivers. They are traced in patches and often in more or less continuous sheets up to a height in some cases of as much as 150 feet above the bottoms of the valleys. It is evident, therefore, that the rivers at one time flowed at elevations which they do not now attain even during the heaviest floods. Professor Prestwich has shown very clearly how impossible it is that the formation of the higher gravel-terraces can be due to the action of the present rivers under existing conditions. "The greatest flood of the Seine on record," he remarks, "is that of the year 1658, when it rose to a height of 29 feet. Even in this case a flood of nearly sixty times that magnitude would be required merely to fill the valley to the level of the high-level gravels, without taking into consideration the more rapid discharge. But neither in this nor in the other cases of modern times are we aware of an increase in the volume of water, during floods in these regions, to many times the ordinary mean average, whereas we see that in a case such as is presented at Amiens a flood having a volume five hundred times that mean would be required to reach the beds of St. Acheul."[1] The conclusion to which this sagacious observer came, therefore, was that the gravels had been laid down by the rivers during the gradual excavation of their valleys ; that is to say that the gravels indicate the various levels at which the rivers formerly flowed. Thus the high-level terraces are those which the streams formed when they were flowing 100 or 150 feet, as the case may be, higher than at present, while the lower terraces on the slopes of the valleys mark out the various stages in the slow process of excavation.

When we bear in mind the fact that, between the time when the higher terraces began to be formed, and the period when the deposition of the lowest-lying Pleistocene beds had been completed, the valleys were excavated in rock to depths ranging from 50 to 150 feet, and to widths that sometimes reach and even exceed a mile, we must be forcibly impressed with the protracted duration of the Pleistocene Period, and the extreme antiquity of its commencement. In the long time that has elapsed since the deposition of the lowest-level Pleistocene beds the valleys have suffered comparatively little denudation, and did we measure the rate at which they were deepened in Pleistocene times with that at which they are now being excavated, we should be compelled to infer for them an almost inconceivable age. There are abundant reasons, however, for believing that their excavation proceeded more rapidly in the past than at present. But even after all due allowance has been made on this score we must still concede for the process of excavation a very prolonged time indeed. It is true that the Cretaceous and Tertiary strata through which so many of the valleys in the south of England and the north of France are cut are by no means so durable as the older rocks of Wales, for example, and the north country generally. Nevertheless, it is obvious that the removal of a mass of Chalk and overlying Tertiary beds, 50 to 150 feet in thickness, and a few yards to upwards of a mile in breadth, throughout the course of a valley 50 or 60 miles or more in length, must have occupied, even at the most rapid rate of denudation, an immense period. We have to conceive of the rocks being gradually undermined, and their fallen *débris* triturated on the bed of the river into gravel, sand, and mud, and rolled gradually seawards. The mere rounding of the flint pebbles, which form a large portion of the old gravel-beds, must of itself have taken a very long time. However rapid, therefore, we may suppose the former rate of excavation to have been, we cannot escape the conviction that the work effected implies an extremely old date for the commencement of the Pleistocene Period.

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[1] *Philosophical Transactions*, 1864, p. 266.

Some idea of the rate at which a valley is excavated might be gathered by carefully estimating the quantity of sediment carried annually by its river into the sea. To get as near the truth as possible it would be necessary to measure first the mean annual discharge of water, and then to ascertain the amount of material held in chemical solution and mechanical suspension, together with that which the water pushed forward on its bed. Unfortunately only a few measurements of this kind have been made, but these, so far as they go, help us to form a more or less adequate conception of the rate at which denudation progresses under present conditions. My brother, Professor A. Geikie, has collected all the available data bearing upon this subject, and comes to the conclusion that those rivers, concerning which he has been able to obtain information, remove one foot of rock from the general surface of their basins in the following ratio :—

The	Mississippi	removes	one foot in	6000	years.
„	Ganges	„	„	2358	„
„	Hoang Ho	„	„	1464	„
„	Rhone	„	„	1528	„
„	Danube	„	„	6846	„
„	Po	„	„	729	„
„	Nith	„	„	4723	„

The Mississippi, therefore, is lowering the surface of the great area it drains at the rate of one foot in 6000 years, which would give 100 feet in 600,000 years. At the rate at which the Po works 100 feet would be removed in 72,900 years. Of course it will be understood that the whole surface of a country does not suffer denudation to an equal degree. Some districts, owing to a variety of circumstances, such as differences in the composition and geological structure of the rocks, inequalities of rainfall, variations in the configuration of the ground, and so forth, are lowered at a more rapid rate than others, the chief amount of waste going on along the course of the valleys. According to the calculations, it appears that the mean annual quantity of detritus carried to the sea may with some probability be regarded as equal to the yearly loss of $\frac{1}{6000}$ of a foot of rock from the general surface of the land, the larger proportion of the loss being sustained by the valleys and sloping surfaces. To apportion this loss between the different parts of a land-surface can of course only be done in a rough-and-ready manner. For the sake of illustration we may assume, with my brother, that the erosion of the surface is nine times greater over the valleys than over the plains and tablelands;—while the more level parts of the country have been lowered one foot, the valleys have lost nine feet. "Apportioning this loss over the surface in the ratio just given, we find that it amounts to $\frac{5}{9}$ of a foot from the more level grounds in 6000 years, and five feet from the valleys in the same space of time. Then if $\frac{5}{9}$ of a foot be removed from the level grounds in 6000 years, one foot will be removed in

10,800 years; and if five feet be worn out of the valleys in 6000 years, one foot will be worn out in 1200 years. This is equal to a loss of only $\frac{1}{12}$ of an inch from the tableland in 75 years, while the same amount is excavated from the valleys in 8½ years."[1] Hence at a rate which may with some reason be taken as the present mean average rate of erosion in valleys, a valley as deep as the Somme, say 150 feet, might be excavated in 180,000 years.

But, as I have said, we have reason to believe that during certain periods of the past the erosion of valleys has proceeded more rapidly than at present, so that the Somme and other ancient river-valleys may have been scooped out in less time than the mean average rate of denudation now in progress would allow. There is abundant evidence to show that the rivers of the Pleistocene Period frequently flowed in much larger volume than the streams of to-day,—that they very often assumed a torrential character, and ever and anon rose in flood and inundated wide tracts of country. Their torrential character is shown by the coarseness of much of the gravel—the flints being often very little rolled—by the absence of mud-sediment, and by the confused and irregular disposition of the bedding—all bespeaking the action of tumultuous waters that hurried along promiscuous heaps of stones and scattered them in confusion over the slopes and bottoms of the valleys, while the finer sediments were swept away in suspension. Where the water of the flooded river was in less commotion the finer sediment held in suspension would be deposited, and this, as Professor Prestwich points out, has doubtless been the origin of many of the so-called brick-earths and löss of such valleys as the Thames, the Somme, the Seine, and their tributaries. They are simply the flood-loams laid down by the same rivers that deposited the valley-gravels. Thus the higher deposits of brick-earth, which rise 60 or 80 feet above the upper gravel-terraces, were formed during floods, when the valleys were beginning to be excavated, while the similar deposits at lower levels were accumulated after the valleys had been deepened to a greater extent. Professor Prestwich illustrates his theory of the origin of the gravels and their accompanying flood-loams by a diagram which

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[1] *Student's Manual of Geology*, Jukes and Geikie, p. 430; see also *Trans. Geol. Soc. of Glasgow*, vol. iii p. 153.

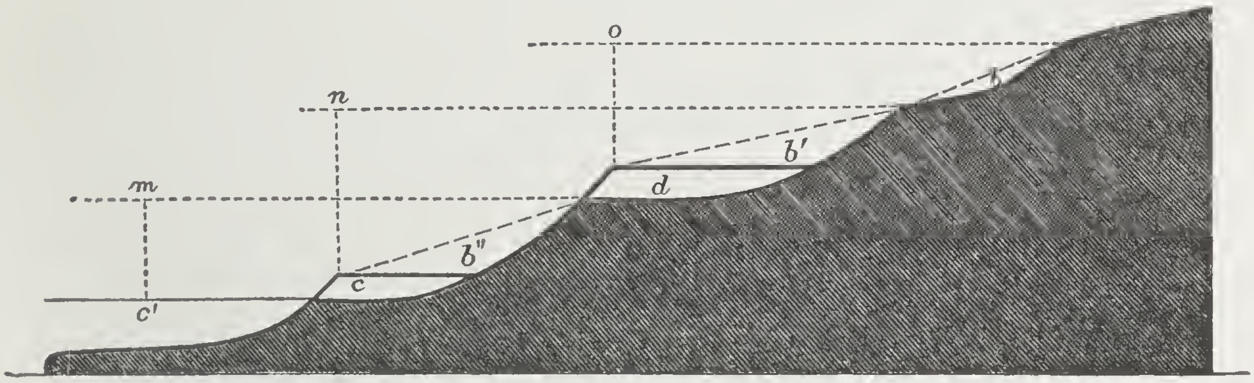

Fig. 4.—Diagram representing one side of a valley, with a series of gravel- and löss-beds. (Prestwich.)

I borrow from his paper (Fig. 4). The diagram is meant to represent one side of a valley with a series of gravel- and brick-earth-beds. When the river flowed on the level *d* it formed the gravel-bed indicated by that letter. During flood-seasons, however, when the water reached to the dotted line *o*, its loamy mud was deposited at *b*. Lower down the slope, that is to say between the loamy mud *b* and the gravel-bed *d*, the scour of the river would prevent any of the finer sediment accumulating. By and by the river excavated its channel to a greater depth, and flowed at the level *c*, where of course another bed of gravel was formed. Being still subject to floods, it is evident that when such was the case, and the surface of the water rose to the dotted line *n*, a second deposit of loam (*b′*) would be laid down upon the old river-bed *d*, and would slope up against the side of the valley to the level of the line *n*. The river still continuing to deepen its channel, a time would come when it would be flowing on the level *c′*, and when loam would be deposited at *b″* on each occasion that the flood-waters rose to *m*, or to any point between *c′* and *m*.

Thus we see how a deposit of loam would eventually come to be spread over all the gravels from the highest to the lowest levels. It may be as well, however; to warn the reader that he must not expect always, or even often, to meet in nature with the regular succession of beds that is indicated upon the diagram. Although it is common to speak of high-level and low-level terraces, the one series really passes down into the other. Neither do these terraces occur continuously on the valley-slopes, forming a series of broad steps or platforms ascending from lower to higher levels. On the contrary, it is often hard or even impossible to distinguish anything like a terrace either in the gravels themselves or in the Cretaceous or other strata upon which they chance to lie. It is doubtful, indeed, whether the gravels would often be spread out so equally as to form flat-topped terraces. It seems much more probable, judging from what we know of rivers that are subject to periodical floods, that they would be distributed very irregularly over the valley-slopes and bottom, forming shoals here and banks there. We must remember, moreover, that while the lower terraces were being formed, the upper ones would tend to become partly obscured by the scouring action of flood-waters, and partly also by the deposition upon them of loam or brick-earth. Again, we should not forget that so long a time must have elapsed between the formation of the upper or oldest and lower or youngest valley-gravels, that the former, after they had ceased to be inundated by floods, would be subjected to the slow but continuous and therefore effective action of the atmospheric agents of waste. Thus, in course of time, it might well be that all trace of a distinctly-terraced feature would disappear, and the gravels would then be reduced to mere patches or interrupted sheets cloaking the slopes of the valleys. Notwithstanding all these changes, however, platforms excavated in the older strata and covered by Pleistocene gravels and loam may now and again be detected.

The size of the stones and the quantity of the material constituting what are called high- and low-level gravels sufficiently indicate, as we have seen, the great transporting power of the Pleistocene rivers, while the brick-earths, with their delicate land-shells, covering all the gravels, and running up the valley-slopes so as to cap the summits of hills far above the level reached by the highest river-gravels, proves the former existence of floods, as Professor Prestwich has pointed out, of extraordinary magnitude. The same geologist has described the occurrence in the valley-gravels of large transported boulders or erratics, some weighing as much as four to five tons, which have been often carried for considerable distances; and besides these he records many examples of contorted or confused bedding which seem to be confined to the higher gravels and loams. The erratics, he believes, have been transported by river-ice, and the disturbed bedding he ascribes to the action of masses of the ice running aground, and digging into the soft deposits upon the river's bed. The fact that the river-ice was so thick as to be capable of carrying blocks of stone weighing several tons renders it more than probable that in Pleistocene times the winter temperature was sometimes at least severe. And this inference, Mr. Prestwich thinks, is further borne out by the character of the fossils met with in the old river-deposits. Thus in regard to the high-level drifts he is of opinion that although the shells which they have yielded have "nothing sufficiently specific in the individual species to indicate a climate different from that of the present day, there is at the same time nothing to require restriction to an identical climate. If, further," he continues, "we look at the group as a whole, we shall find it to have not only a very wide range, but one more in a northern than in a southern direction." The few plant remains which have been met with in these higher beds afford somewhat similar evidence—they all belong to species which, although common in our latitudes, have yet a considerable northern range, and there appears to be an absence of southern forms. The evidence supplied by the mammalian relics (which include remains of the mammoth, *Elephas antiquus*, the woolly rhinoceros, the horse, the urus, the reindeer, etc.) does not seem, according to the same authority, to militate against that furnished by the testacea and the land-plants. All the recent species of molluscs and plants "are such as are now to be found within the limits of the temperate zone, but they appear to agree better with the fauna and flora of its northern than of its southern provinces. The fossil mammalia may also, from their general association and distribution, be considered to have inhabited cold countries, so that there is a balance in favour of a severer, but not of an extreme, climate."

As regards the low-level gravels the fossil evidence is somewhat more abundant. The shells upon the whole maintain their general northern character, but the group contains a few more southern land and freshwater species, which seem to indicate a less extreme climate. "The profusion also of the land and freshwater testacea, and the greater variety and abundance of animal life, support this latter view." The mammalian remains include the species mentioned above as occurring in the high-level gravels, as also *Rhinoceros megarhinus*, cave-bear, cave-hyæna, cave-tiger or lion, bison, musk-sheep, hippopotamus, etc. Mr. Prestwich thinks that there is nothing in this assemblage of animals that would lead us to infer other than a rigorous climate. He suggests that the hippopotamus may have been furnished with a woolly coat to protect him against the cold, just as was the case with the mammoth and the tichorhine rhinoceros. I have already discussed the evidence of the mammalia as to the climate of Pleistocene times, and shown that all the animals could not have occupied the same feeding-grounds at the same time. One fatal objection to Mr. Prestwich's suggestion in regard to the hippopotamus is based upon the aquatic habits of the animal. It is hardly possible that it could live in a country whose rivers were liable to be frozen over every winter. The presence of the northern forms is clearly indicative of cold climatic conditions, during the continuation of which the vegetation must have been poor and scanty, not more varied and abundant than that which characterises the "barren grounds" of North America and the tundras of Northern Europe and Siberia. The hippopotamus was not likely to occupy a country with such a climate. Mr. Dawkins well remarks, "It could not have endured a winter sufficiently severe to cover the rivers with a thick coating of ice without having its habits profoundly modified; and such an alteration of habits would certainly leave its mark in other modifications in the fossil skeleton than those minute differences which have been observed when it has been compared with that of the living *Hippopotamus amphibius*."[1] The occurrence of remains of the cave-haunting bears, lions, and hyænas, and of the bison and other herbivores, is further indicative of a climate capable of nourishing vegetation sufficiently abundant to sustain the herds of oxen, deer, and other animals upon which the great carnivora preyed. And the truth of this inference is greatly strengthened, and even as it seems to me entirely confirmed, by the facts already set forth in regard to the land-plants and mollusca which have left their remains in such deposits as that of La Celle, which clearly belongs to the ancient Pleistocene accumulations of the Seine valley, overlying as it does the so-called *diluvium gris*, or gray gravel, and belonging, according to M. Tournouër, to a late stage of the Pleistocene Period. In short, the evidence supplied by the old "river-drifts"—those of high and low level alike—is of precisely the same character as that of the caves. It speaks to us of alternations of mild or genial and cold climatic conditions. If the evidence of a cold climate seems to predominate, it is only what we might have expected. It was during the continuance of such a climate that the rivers would be most energetic, ploughing into the rocks through which they flowed, and pushing enormous quantities of detritus down their valleys. As each spring returned, wide tracts of country would be inundated, and many animals might be drowned, and their disjointed skeletons eventually come to be entombed in silt and sand. In like manner such loose bones or other waifs as lay bleaching on the ground would often be swept away, with other *débris*, by the floods. For floods and inundations are the rule in all countries which are subject to severe winter cold; whereas they are the exception in genial temperate climates. Hence the river-deposits of a cold period would be thicker and more widely spread than those which were accumulated at a time when the climate was genially temperate. And again, the remains of arctic and northern animals would be distributed through a wider range of deposits, and might in some cases be relatively more abundant than those of southern and temperate species.

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[1] *Cave-hunting*, p. 374.

It has sometimes been urged against these views that if the northern and temperate and southern species had occupied a country at different periods, their bones would always occur in separate and distinct deposits. We ought, it has been said, to meet with beds containing remains of the northern animals alone, overlying or underlying, as the case might be, strata in which only the relics of southern or of temperate species should occur. Now, if it were true that rivers did nothing but pile one layer of gravel, sand, or mud upon another—always depositing, and never rearranging what had already been laid down—we might well have looked for some such arrangement as that which I have referred to. Or again, if the period during which one group of mammalia occupied the ground was so prolonged that the rivers were able to erode their valleys to a great depth, so as to leave the slopes covered with successive deposits charged here and there with animal remains, it might happen that, after the old group of animals had disappeared, and another group had succeeded, the last series of alluvial terraces would not contain a single relic of the former, but only remains of the latter. There is not the slightest reason, however, for believing that the alternations of climate were each of such protracted duration. Moreover, the rivers, even up to the close of Pleistocene times, were able to flood their valleys to a very great height, and so to bring the older gravel-deposits under their influence.

No one who shall examine any well-developed river-deposits of Pleistocene age, such as those of the Thames, or of the valleys in the north of France, can fail to see that they all form part of one and the same series. They point to the long-continued action of erosion and deposition, and doubtless the river that transported the sediments, and spread them out where we now see them, behaved in precisely the same manner as any other river at the present day. Gravel was laid down here, sand there, and mud in some other place; then, owing to changes in the direction or velocity of the current, these deposits were disturbed, broken up, wholly or partially, and their materials distributed over another part of the river's bed. After a considerable accumulation of such deposits had taken place—many feet or even yards in depth,—the river might again gradually undermine and re-arrange them. The gravel would be pushed along and come to rest farther away, and so would it be with the sand and silt. Any animal remains, such as bones or teeth, which these older deposits may have contained would in like manner be rolled along and embedded in another position. Thus in a series of fluviatile strata like the Pleistocene gravels and sands, it is often quite impossible to tell whether the animal remains that lie side by side in the same stratum belong to species that were exactly contemporaneous, in the sense of occupying the same country at the same time. Sir Charles Lyell has some remarks upon this subject which are so apposite that I cannot do better than quote them in full. He says:[1] "In attempting to settle the chronology of fluviatile sediments, it is almost equally difficult to avail ourselves of the evidence of organic remains, or of the superposition of the strata, for we may find two old river-beds on the same level in juxtaposition, one of them perhaps many thousands of years posterior in date to the other. I have seen an example of this at Ilford, where the Thames, or a tributary stream, has at some former period cut through sands containing *Cyrena fluminalis*, and again filled up the channel with argillaceous matter, evidently derived from the waste of the Tertiary London-clay. Such shiftings of the site of the main channel of the river, the frequent removal of gravel and sand previously deposited, and the throwing down of new alluvium, the flooding of tributaries, the rising and sinking of the land, fluctuation in the cold and heat of the climate—all these changes seem to have given rise to that complexity in the fluviatile deposits of the Thames, which accounts for the small progress we have hitherto made in determining their order of succession, and that of the embedded group of quadrupeds. It may happen, as at Brentford and Ilford, that sand-pits in two adjoining fields may each contain distinct species of elephant and rhinoceros; and the fossil remains in both cases may occur at the same depth from the surface, yet may be specially referable to different parts of the Pleistocene Epoch, separated by thousands of years." We cannot therefore infer from the occurrence of the horns of a reindeer and the remains of a hippopotamus, in juxtaposition in a Pleistocene deposit, that these animals have lived under similar climatic conditions. It must not be supposed, however, that such intimate commingling of strongly-contrasted species is the rule. Not infrequently we find remains of several northern animals lying associated in the same strata to the entire exclusion of any of the southern forms; and in like manner the latter often appear quite unaccompanied by any trace of the northern species. Thus at Gray's Thurrock in Essex, the old Pleistocene alluvia of the Thames have yielded *Elephas antiquus, Rhinoceros leptorhinus, Hippopotamus major,* horse, bear, ox, stag, etc., but not a trace of any northern species. In the same beds occur *Cyrena fluminalis, Unio littoralis,* and *Paludina* (*Hydrobia*) *marginata,* which is no longer a British shell, but still lives in the south of France.

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[1] *Antiquity of Man*, 4th edition, p. 206.

But although it is unsafe to rely exclusively upon superposition as a test of the relative antiquity of fluviatile accumulations, yet as a general rule it still holds true that the beds which occupy the lower portion of any thick series will be, in the main, the oldest; while, on the other hand, those at the top will commonly be the youngest. Again, in the case of those river-deposits that cloak the slopes of a valley, we may feel sure that those at the highest levels will be the oldest, and that the younger accumulations will occupy the lower levels; but the latter will frequently overlap upon the former, and the two will even in many cases be inextricably commingled. Nevertheless, the general rule will still obtain, the high-level beds will in the main belong to the oldest stage of the series. Now as it would appear that remains of musk-sheep and reindeer, mammoth, woolly rhinoceros, hyæna, lion, elephant, hippopotamus, bison, and other animals belonging to the northern, temperate, and southern groups, occur at all levels in the Pleistocene river-deposits, it seems only reasonable to conclude that these groups must have occupied the ground alternately throughout the whole of the Pleistocene Period.

The general glance which we have taken at the more salient features of the evidence presented by our Pleistocene river-deposits, makes clear, as it seems to me, the following points :—

1. They are the products of fluviatile action, and were formed during the excavation of the valleys in which they lie.

2. They were laid down under varying conditions, some of the deposits indicating quiet and orderly accumulation, others bespeaking tumultuous torrential waters and vast inundations. But the wider spread of torrential gravels and flood-loams does not necessarily imply that a cold climate predominated during Pleistocene times.

3. Their fossil organic remains point to alternating climatic conditions—to periods more or less prolonged when the cold of winter was severe, and the land was occupied by northern and arctic forms, and to warmer periods (enduring, perhaps, for as long a time as the colder ones), when the winters were extremely mild and genial, so that laurels and fig-trees grew on the banks of the Seine, while an abundant mammalian fauna occupied the land, the hippopotamus being enabled to live as far north as the latitude of Yorkshire.

4. The depth and width attained by many of the valleys which were excavated during the Pleistocene Period, and the time required for great continental changes of climate, such as are implied by the presence of the old mammalia, are proofs of the long duration of the Pleistocene Period, and the remote antiquity of its commencement.

5. During the prevalence of cold climatic conditions the erosion of valleys would proceed at a more rapid rate than is the case in our latitude at present, and any calculation of the antiquity of Pleistocene fluviatile deposits which should be based upon the rate of denudation now in progress would most probably be exaggerated, not necessarily to such an extent, however, as might at first sight appear ; for, during the milder periods, or period when hippopotamuses lived in the north of England, denudation would proceed less rapidly than when the climate was arctic, and thus the one rate might to a certain extent balance the other.

But while it may be admitted that the views so ably expounded by Mr. Prestwich are capable of a wide application, and will explain the phenomena presented by the Pleistocene valley-gravels throughout Europe generally, yet they fail to account for the origin of certain gravelly accumulations which have yielded both mammalian remains and Palæolithic implements. I refer to those sheets of coarse gravel and detritus which spread often continuously over wide districts in Southern England. They are not confined to valley-slopes, but sweep up and over hill-tops, valley-partings, and watersheds ; extend across plateaux and platforms between separate valleys ; and, in short, bear little or no relation to the present drainage-systems of the country. It is not possible that those gravels could have been laid down by rivers in the process of deepening their valleys,—their distribution and general appearance show that the surface had already received much of its present contour before the deposits were scattered broadcast over the country. I should mention that the deposits in question are frequently very coarse and rudely bedded. They often show a confused and tumbled appearance, consisting of sand, grit, angular *débris* and blocks, and well-rounded stones, promiscuously heaped and jumbled together. And what is particularly noteworthy, many of the stones are often standing on end, and not lying in the position they might have been expected to assume had they been laid down by ordinary river-action.

The origin of these gravels has always been a difficult question, but a suggestion which Mr. Darwin some years ago (1876) did me the honour to communicate gives what appears to be the true explanation of the somewhat puzzling phenomena. Having since had an opportunity of testing the value of the suggestion referred to, I have found it extremely helpful, and believe that my co-workers will agree with me in this opinion. Mr. Darwin, after remarking that his observations were made near Southampton, writes as follows:—"I need say nothing about the character of the drift there (which includes Palæolithic celts), for you have described its essential features in a few words (*Great Ice Age*, p. 506). It covers the whole country, even plain-like surfaces, almost irrespective of the present outline of the land. The coarse stratification has sometimes been disturbed; and I find that you allude to 'the larger stones often standing on end,' which is the point that struck me so much. Not only moderately-sized angular stones but small oval pebbles often stand vertically up, in a manner which I have never seen in ordinary gravel-beds. This fact reminded me of what occurs in my own neighbourhood in the stiff red clay, full of unworn flints, over the chalk, which is no doubt the residue left undissolved by rain-water. In this clay flints as long and as thin as my arm often stand perpendicularly up, and I have been told by the tank-diggers that it is their 'natural position'! I presume that this position may safely be attributed to the differential movement of parts of the red clay, as it subsided very slowly from the dissolution of the underlying chalk, so that the flints arrange themselves in the lines of least resistance. The similar but less-strongly marked arrangement of the stones in the drift near Southampton makes me suspect that it also must have slowly subsided, and the notion has crossed my mind that during the commencement and height of the Glacial Period great beds of frozen snow accumulated over Southern England, and that during the summer gravel and stones were washed from the higher land over its surface, and in superficial channels. The larger streams may have cut right through the frozen snow, and deposited gravel in lines at the bottom. But at each succeeding autumn, when the running-water failed, I imagine that the lines of drainage would have been filled up with blown snow, afterwards congealed ; and that owing to the great surface-accumulations of snow it would be a mere chance whether the drainage, together with gravel and sand, would follow the same lines during the next summer. Thus, as I apprehend, alternate layers of frozen snow and drift in sheets and lines would ultimately have covered the country to a great thickness, with lines of drift probably deposited in various directions at the bottom by the larger streams. As the climate became warmer the lower beds of frozen snow would have melted with extreme slowness, and during this movement the elongated pebbles would have arranged themselves more or less vertically. The drift would also have been deposited almost irrespective of the outline of the underlying land. When I viewed the country I could not persuade myself that any flood, however great, could have deposited such coarse gravel over the almost level platforms between the valleys."

Mr. Darwin writes me again recently to say that subsequent observations near Southampton and elsewhere have only tended to strengthen him in his conclusion. Referring to the structure of his own neighbourhood (Beckingham, Kent), he says the chalk-platform slopes gently down from the edge of the escarpment (which is about 800 feet in height) towards the north, where it disappears below the Tertiary strata. "The beds of the large and broad valleys, and only of these, are covered with an immense mass of closely-packed, broken, and angular flints, in which mass remains of the musk-sheep and woolly elephant have been found. This great accumulation of unworn flints must therefore have been made when the climate was cold, and I believe it can be accounted for by the large valleys having been filled up to a great depth during a large part of the year with drifted frozen snow, over which rubbish from the upper parts of the platforms was washed by the summer rains and torrents, sometimes along one line and sometimes along another, or in channels cut through the snow all along the main course of the broad valleys."

CHAPTER IX.

LOAMY DEPOSITS OF THE PLEISTOCENE PERIOD.

Löss of German geologists—Its distribution throughout Europe—Organic remains of the löss—Dr. Nehring on loamy deposits of Thiede and Westeregeln—Mammalian and human remains in löss—Changes in composition of löss—River-gravels and lignite underlying löss—Löss of Northern France—Its relation to *Diluvium gris* and *Diluvium rouge*—*Terre à briques* and *Limon grossier*—Fossils of French löss—Belgian löss—Its organic remains—M. Dupont on Belgian löss and associated deposits—*Tchernozem*, or black-earth of Russia—Theories of the origin of löss—Views of Bennigsen-Förder, Hibbert, Gümbel, Lyell, Prestwich, Tylor, A. Geikie, Belt—Murchison on origin of black-earth—De Mercey on origin of French limon—D'Acy's views on same—Baron Richthofen's löss-theory—Mr. Pumpelly's views.

ALTHOUGH Professor Prestwich's observations are restricted to the old river-drifts of the south of England and the north of France, they nevertheless hold true, to a large extent, as I believe, for many similar accumulations in other countries. All the great rivers of Europe flow through valleys which are clothed more or less continuously with sheets of gravel, sand, and loam that rise to heights far beyond the reach of the heaviest floods of modern times. And the same is the case with very many of the tributaries of these rivers. Indeed, there is perhaps no considerable river-valley that does not bear evidence of having been subjected at some geologically recent period to inundations of much greater magnitude than are ever experienced now. The more widely-spread deposits, which are supposed to bear witness to these floods, are known under various names, such as *ancient alluvium, loam, brick-earth*, etc., in this country, löss, lehm, etc., in Germany, *limon, terre à briques*, etc., in France and Belgium. Mr. Prestwich, as we have seen, considers these sheets of loam as forming part and parcel of the ancient river-accumulations of the Pleistocene Period. But they attain so great a development in various parts of Europe, that many geologists have hesitated to accept this explanation of their origin. Nor can it be denied that the phenomena are sometimes produced on so grand a scale that even the most exaggerated river-action seems hardly to account for them. Geologists, therefore, have very generally discussed the question of the origin of the great loamy deposits of the Pleistocene Period apart from that of the ancient gravels, with which the former are usually associated in the valleys. I believe, nevertheless, with Professor Prestwich, that the explanation of the one set of phenomena is bound up with that of the other—that the loams and gravels in short are terms of one and the same series. For the present, however, I shall follow other geologists in considering the loamy deposits by themselves, and shall reserve what I have to say about their origin to a subsequent chapter.

One of the most representative and typical of the accumulations now under review is the *löss* of German geologists. This may be shortly described as a yellow or pale grayish-brown, fine-grained, and more or less homogeneous, consistent, non-plastic loam, consisting of an intimate admixture of clay and carbonate of lime. It is frequently minutely perforated by long vertical root-like tubes which are lined with carbonate of lime —a structure which imparts to the löss a strong tendency to cleave or divide in vertical planes. Thus it usually presents upright bluffs or cliffs upon the margins of streams and rivers which intersect it. Very often it contains concretions or nodules of irregular form, which are known in the Rhine district as *Lössmännchen* or *Lösspüppchen,* and in that of the Danube as *Lösskindeln.* Land-shells and the remains of land-animals are the most common fossils of the löss, but occasionally freshwater shells and the bones of freshwater fish occur. Such is the typical character of löss. It is not, however, always an unstratified mass. Often enough lines of bedding, a foot or more apart, may be traced running horizontally across the face of a deep cutting; and now and again intercalated layers and laminæ of sand make their appearance. Here and there too we may encounter stones either isolated or in little patches and groups, and in places where the accumulation abuts against a cliff or rock-slope, it not infrequently contains intercalated lines and layers of fragments which have evidently been detached from the adjacent rocks and embedded during its formation. Again the löss of some regions loses to a large extent its carbonate of lime, becomes more argillaceous and passes into a plastic clay, in which condition it would cease to be called löss by sticklers for precise terminology. Or it may graduate into a loam, distinguished from löss merely by the paucity or absence of carbonate of lime. As the löss is a deposit of mechanical and not of chemical origin, we are prepared to meet with such changes in the character of the accumulation. The definition of the typical löss given above applies more particularly to that of Central Europe—to the great löss-deposits of the valleys of the Rhine, the Rhone, and the Danube. In northern France and in the south of England accumulations which occupy the same geological horizon often differ very considerably from the löss of the Rhenish districts, and the same is the case with vast sheets of loam that overspread the south of Russia. The one character which all these deposits have in common is their extremely fine texture. In other respects they frequently offer considerable contrasts. As a rule they form admirable soils, and it is to them that many of the most productive regions of Europe owe their fertility.

Löss, as I have said, is typically developed in the regions watered by the Rhine and its tributaries. From the margins of the modern alluvial flats which form the bottoms of the valleys it rises to a height of 200 and 300 feet above the streams—sweeping up the slopes of the valleys, and imparting a rich productiveness to many districts which would otherwise be comparatively unfruitful. From the Rheinthal itself it extends into all the tributary valleys—those of the Neckar, the Main, the Lahn, the

Moselle, and the Meuse, being more or less abundantly charged with it. It spreads, in short, like a great winding-sheet over the country—lying thickly in the valleys and dying off upon the higher slopes and plateaux. Wide and deep accumulations appear likewise in the Rhone valley, as also in several other river-valleys of France, as in those of the Seine, the Sâone, and the Garonne, and the same is the case with many of the valleys of Middle Germany, such as those of the Fulda, the Werra, the Weser, and the upper reaches of the great basin of the Elbe. It must not be supposed that the löss is restricted to valleys and depressions in the surface of the ground. It is true that it attains in these its greatest thickness, but extensive accumulations may often be followed far into the intermediate hilly districts and over the neighbouring plateaux. Thus the Odenwald, the Taunus, the Vogelgebirge, and other upland tracts, are cloaked with löss up to a considerable height. Crossing into the drainage-system of the Danube, we find that this large river and many of its tributaries flow through vast tracts of löss. Lower Bavaria is thickly coated with it, and it attains a great development in Bohemia, Upper and Lower Austria, and Moravia —in the latter country rising to an elevation of 1300 feet. It is equally abundant in Hungary, Galicia, Bukowina, and Transylvania. From the Danubian flat-lands and the low grounds of Galicia it stretches into the valleys of the Carpathians, up to heights of 800 and 2000 feet. In some cases it goes even higher —namely, to 3000 feet, according to Zeuschner, and to 4000 or 5000 feet, according to Korzistka. These last great elevations, it will be understood, are in the upper valleys of the northern Carpathians. In Roumania löss is likewise plentiful, but it has not been observed south of the Balkans. East of the Carpathians, that is to say, in the regions watered by the Dniester, the Dnieper, and the Don, löss appears also to be wanting, and to be represented by those great Steppe-deposits which are known as "Tchernozem" or black-earth, and to which I shall refer presently.

Continental geologists speak of "hill-löss" and "valley-löss," by which they indicate merely a difference of level and not of composition. All those tracts of löss which occur within the valleys proper come under the designation of valley-löss, while the term "hill-löss" is applied to those masses which are less closely connected with the valleys, and sometimes extend over plateaux and hilly ground between separate drainage-areas. As already pointed out, löss attains its greatest thickness in the valleys; as we leave these and follow it up the slopes it becomes thinner, until it more or less suddenly disappears. Upon the higher slopes and plateaux it rarely exceeds a few feet in thickness.

A list of löss-shells has been already given (see p. 60), and it may be taken as eminently characteristic. It will be remembered that the shells imply colder and wetter conditions of climate than now obtain in Middle Europe. Amongst the mammalian remains which have been recorded from the löss are reindeer, glutton, lemming, various species of rat and mouse, jerboa, marmot, pouched marmot, horse, hyæna, cave-bear, urus, bison, mammoth, woolly rhinoceros, etc. As a rule these species are represented by only detached bones, tusks, horns, etc. Perfect, or nearly perfect, skeletons of the larger animals seem rarely or never to occur. But now and again some of the smaller species have been met with in a tolerably perfect condition. Among the most interesting discoveries of the kind are those recorded by Dr. Nehring from Thiede and Westeregeln.[1] Thiede lies a little to the north-west of Wolfenbüttel in Brunswick, and Westeregeln about midway between Magdeburg and Halberstadt in Saxony. As the fauna obtained from those two localities may be considered typical of the löss, I shall give a brief digest of the facts which Dr. Nehring has made known. The deposits at Thiede show three stages, which in descending order are as follow:—

1. *Uppermost Stage*, extending from the surface down to

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[1] "Die quaternären Faunen von Thieden und Westeregeln, nebst Spuren des vorgeschichtlichen Menschen," *Archiv für Anthropologie*, Bd. x. and xi., 1878 *Verh. der k.-k. geol. Reich.*, 1878, p. 261.

about fourteen feet. The beds of this series consist of loam with a general löss-like character, which is most strongly pronounced towards the bottom, where the colour of the deposit is bright yellow. At that horizon it is strongly calcareous, has the well-known tubular or capillary structure, is very fine in the grain, shows little or no trace of bedding, has very little or even no plasticity, and contains characteristic löss-shells, such as *Pupa muscorum, Succinea oblonga, Helix hispida,* etc. The uppermost portion, from one to nine feet down, is rendered more or less dark-coloured by the presence of carbonaceous matter; some parts when wet are even quite black. About seven feet or so from the surface many pieces of oak occur, but other organic remains are not common. Lower down come remains of a large ox, lion, etc.

2. The *Second* or *Middle Stage* extends from the bottom of the overlying beds down to twenty-two feet from the surface, giving a thickness of eight feet. The beds of this stage are not true löss but rather calcareous clays, containing not a few rounded and angular stones, chiefly flint, but quartz, granite, and other varieties also occur, some of the fragments having evidently been derived from the so-called "Northern Drift," of which I shall speak in a later chapter, while others may have come from the Harz Mountains and districts to the south or south-west. One fragment of red granite must have weighed over twenty pounds. The most abundant organic remains in this bed are those of the mammoth and woolly rhinoceros, and next to these are the horse and a kind of ox. The hyæna and the reindeer are rarer.

3. The *Third* or *Lowest Stage,* consisting of alternations of thin sandy and loamy layers, begins at about twenty-two feet from the surface, and extends to the bed-rock of the neighbourhood at a depth of from thirty to thirty-five feet, and sometimes as much as forty feet from the soil. The line of demarcation between it and the clays of the overlying middle stage is clearly defined. The most abundant remains in this stage are those of lemmings—*Myodes lemmus* (common or Norwegian lemming)

being particularly abundant in the upper layers, while *M. torquatus* (torquated lemming) predominates in the lower-lying beds. The other species associated with the lemmings are *Arvicola gregalis* (Siberian social-vole), and old and young individuals of the Arctic fox and reindeer. Confined to the upper part of the stage are *Equus caballus* (horse), *Arvicola ratticeps* (Northern field-vole), *A. amphibius* (water-vole), and species of lagomys, spermophile, and bat. The beds contain a considerable admixture of lime, which often forms concretions round the bones, and now and again gravel-stones make their appearance. In this lowest stage occurred various relics of man—old hearths and flint implements. Although a clearly-marked line separates the lowest from the middle stage, it is to be observed that remains of the lemming occur sporadically in the lower portion of the mammoth-beds (Stage 2), while traces of the mammoth in like manner are met with in the upper portion of the lemming-beds (Stage 3).

The section at Westeregeln also shows three stages, which, however, do not correspond precisely with those at Thiede. The upper and middle stages at the former locality consist of bedded deposits, which have a more or less löss-like appearance; but they are generally coarser in the grain than typical löss. They contain, besides several characteristic löss-shells, a number of mammals, including *Alactaga, Spermophilus, Arctomys bobac, Lagomys pusillus,* and several species of *Arvicola.* These are most common at a depth of from 12 to 18 feet; above and below this horizon they occur only at intervals. Along with the species just mentioned come also mammoth, woolly rhinoceros, and reindeer, and other so-called "diluvial" animals. The lowest beds of Westeregeln, occurring at a depth of 20 to 30 feet, are distinctly stratified, and consist of alternations of sand and clay. They contain such shells as *Cyclas* (*cornea?*) and *Planorbis carinatus,* and occasional stones. If we except their calcareous nature the beds have nothing apparently in common with true löss; they have yielded remains of the lemming, but not so abundantly as the beds at Thiede. Other species associated with the lemming at Westeregeln are woolly rhinoceros, horse, reindeer, hyæna, and sometimes mammoth. Rodents and bats are rare. Nehring correlates the upper and middle stages at Westeregeln with the highest stage and the upper part of the middle stage at Thiede—the lowest stage at Westeregeln corresponding to the mammoth-beds of Thiede. He considers, therefore, that the lowermost stage (the lemming-beds) of Thiede has no representative in the Westeregeln series.

The lower beds at Westeregeln have yielded traces of man, such as flint-flakes, charred wood, and heaps of smashed and crushed bones of various animals.

It is seldom that so rich a series of organic remains has been obtained from the löss of any one locality. As a rule mammalian relics occur only at wide intervals, and they are generally in a very fragmentary condition; but in the cases so admirably described by Nehring they are most abundant, and many of the skeletons are tolerably perfect, showing that they could not have come from any distance, an inference which is in keeping with the generally unrolled character of the stones, and the state of preservation of the fragments of wood.

Mammoth, woolly rhinoceros, reindeer, horse, ox, etc., have been recorded from the löss of many other parts of Central Europe. Prinzinger and Czjzek mention mammoth, woolly rhinoceros, and *Cervus dama gigantea* as occurring in the löss of Upper and Lower Austria; Zeuschner has observed a similar fauna (mammoth, rhinoceros, and *Bos priscus*) in some of the valleys of the North Carpathians; according to Dr. Roemer, mammoth, woolly rhinoceros, *Bison priscus*, and urus occur in the löss of Silesia; and Hauer and Stache state that the two pachyderms appear in association with the reindeer and the horse in the löss of Transylvania. The same species, along with ox, characterise, according to Dr. Littel, the löss and lehm of Bavaria, and a similar tale might be told of the equivalent accumulations in many other parts of the Continent. Dr. Sandberger's catalogue of the mammalian fauna from the löss of Franconia has been given above (see p. 62), and it may be taken as typical of the löss of the Rhenish districts. The only relic of man, noted by Sandberger, is one of the bones of the finger; but human remains were found many years ago by M. Ami Boué in the löss near Strasbourg, and the well-known "Eguisheim cranium" came from löss, in which it was associated with remains of mammoth, lion, stag, horse, etc. Again, a human jaw was obtained underneath löss near Maestricht, at a depth from the surface of 19 feet, and a human skull is said to have been obtained in löss near Mannersdorf. One of the most interesting discoveries of human relics in löss is that made by Count Wurmbrand near Zeiselberg, at the mouth of the Kamp valley. At that place the undisturbed löss yielded a rich deposit of bones, underneath which occurred a blackish stratum, abounding with fragments of charcoal and worked flints. The associated mammalian remains included mammoth, rhinoceros, reindeer, horse, ox, wolf, and bear; and from the general appearance presented by these and the human relics, it was evident that they could not have been transported from any distance.

Such is the general character of the löss of Central Europe. In all the great valleys which directly or indirectly drain the Alps, the deposit is remarkably homogeneous and alike in almost every respect, and the same is to a large extent true of the löss in tributary valley-systems. But in the upper reaches of the latter some difference may often be detected. Thus in that of the Neckar, near Tübingen, Lyell observed that the löss was very distinct in colour and composition from ordinary Rhenish löss, being mottled with red and green. These appearances are only explicable on the supposition that the main body of the löss of such valleys as the Rhine and the Danube has been derived in large measure from the wearing away of the Alps, the material obtained from other sources being commingled with and lost, as it were, in the superabounding detritus of Alpine origin. Only in the upper reaches of the tributary valleys does a local character impress itself upon the löss. Its mottled appearance in the neighbourhood of Tübingen, for example, is evidently due to the fact that it owes its origin in great part to the degradation of certain variegated red sandstones which are common in that region.

The löss almost invariably rests upon gravel. This is the rule in valleys, and these gravels are unquestionably of fluviatile origin. They are indeed of the same age and origin as the ancient river-gravels of Northern France, and have, like them, yielded numerous remains of the old mammalia, as at Mosbach near Biebrich, and Schierstein. More than this, we find that the fauna comprises representatives from all the three groups—northern, temperate, and southern. Now and again valley-löss is underlaid by a kind of lignite or brown coal. Here, for example, is a section of the löss and lignite-beds of Steinbach near Baden-Baden, as given by Dr. F. Sandberger:—[1]

SECTION, 200 feet above RHINE.

	Feet.	Inches.
1. Löss with *Helix arbustorum*, and its var. *alpestris*, *Helix hispida*, *Pupa dolium*, *P. columella*, *P. muscorum*, *Clausilia dubia*, *Succinea oblonga*	7	0
2. Coarse sand	0	1½
3. Yellow loam or clay	0	2
4. Coarse sand	0	8
5. Yellowish gray clay	2	0
6. Light grayish blue clay . . .	10	0
7. "Moor coal," with leaves, trunks, and branches of *Betula pubescens*, seeds and leaves of *Menyanthes trifoliata*	1	0

But when the löss is followed to levels higher than those reached by the highest valley-gravels, it may come to rest directly upon glacial deposits.

The löss of the French river-valleys has a general resemblance to that of the Rhine and other valleys of Central Europe. And this is more particularly the case with the Rhone, as we might have expected. In the north of France the löss, while retaining the character of a sandy calcareous loam, yet frequently becomes more or less argillaceous, and even passes into a regular brick-earth. Or it may consist of a succession of alternate layers of brick-earth and calcareous loam or löss properly so called. In the valleys of the Seine, the Somme, and other streams in the north, it overlies those ossiferous and implement-bearing gravels, which are known to French geologists as *diluvium gris* and *diluvium rouge*. The gray calcareous diluvium or gravel, as we may call it, from its prevailing character, differs from the overlying red non-calcareous diluvium chiefly in colour. In point of fact the red diluvium is often only the discoloured upper portion of the gray gravel. It is also certain that the so-called "red diluvium" which is found resting directly upon the chalk over wide areas in Northern France is not of fluviatile origin at all, but simply the insoluble residue of red earth and flint which has resulted from the long-continued action of acidulated rain-water upon the chalk. This "red diluvium" may be followed through extensive districts in every country where Cretaceous strata are well developed. But the reddish-coloured gravel and earth that overlie the gray diluvium of the valleys and valley-slopes are unquestionably fluviatile—their colour and present condition being simply the results of chemical changes, which have influenced the calcareous gray diluvium in the same way as they have acted upon the Cretaceous strata. Sometimes, indeed, we may observe a similar discoloration in the upper part of the löss, which in these cases appears to be overlaid by a later deposit of red earth. This appearance, however, is deceptive, and like the others is due to the chemical action of acidulated water soaking into the löss from the surface. The line between the red earth and the yellow löss is generally very uneven, but occasionally it may approach horizontality, when the acid-water has been stopped in its descent by some lamina or layer of impermeable argillaceous matter.[1]

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[1] "Geol. Beschreibung der Gegend von Baden-Baden," *Beitr. z. Statistik der innern Verw. d. Grossh. Baden*, Heft. xi. p. 7; *Die Land- und Süsswasser-Conchylien der Vorwelt*, p. 761.

Löss or loam may be said to cloak all the plains or plateaux of the north and north-east of France up to heights of 600 or 700 feet above the sea. In the valleys, as I have said, it reposes upon gravels, but above the level to which these extend it lies either upon so-called "*diluvium rouge*" or upon the basement-rock, which in those regions is generally chalk. The French löss usually consists of an upper very fine-grained, non-calcareous reddish portion (*terre à briques*), which is extensively used for brickmaking, and a lower lighter coloured portion (*limon grossier*) which is coarser, more or less calcareous, and seldom or never plastic or suitable for bricks. Frequently the under part of this *limon grossier* is charged with broken and cracked flints, which have not been rolled about, but are sharply angular, and have evidently not travelled far.

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[1] On the origin of the red-coloured gravel or diluvium and löss of Northern France, see papers by MM. Meugy (*Bull. Soc. Géol. France*, 3^e Sér. t. v. p. 226) and Vanden Broeck, *Op. cit.*, pp. 298, 326.

The fossils of the French löss consist chiefly of land-shells, with here and there (in the valley-löss) a river-shell. Most of the species are still natives of Northern France, some, however, having now a more northerly range. The mammalian remains, like those of the German löss, are chiefly of temperate, boreal, and alpine forms, such as mammoth, woolly rhinoceros, horse, urus, saiga, reindeer, marmot, ibex, etc. Palæolithic implements have likewise been discovered in and underneath the löss of the Seine, the Somme, and other valleys. I may add that as a rule the löss or *limon* of the plateaux is poor in organic remains of any kind.

Although the löss occurs upon the plateaux and hills up to a height of nearly 350 feet above the bottoms of the larger river-valleys, such as that of the Seine, it is yet always bounded, as Mr. Prestwich remarks, by higher hills flanking the plains and the lower ranges. Beyond its limits the only superficial accumulation we encounter is a reddish ochreous earth charged with flints, which is merely the decomposed upper surface of the Chalk, and to which the name of *diluvium rouge* has often been applied.

Passing into Belgium we are confronted with similar phenomena. The ancient Pleistocene gravels with their mammalian remains are confined as in France to the valleys, where they are overlaid by loamy deposits (*Limon hesbayen*), which sweep up to higher levels and extend across the plateaux. These latter consist of a lower yellowish, unstratified, fine-grained, calcareous loam or löss, from 6 feet to 30 or 40 feet in thickness, and an upper reddish or brown, unstratified, non-calcareous, and argillaceous loam, which is often sufficiently plastic to be used for the making of bricks. Above the limits of the ancient valley-gravels these loamy deposits are often underlaid by sandy earth and stones, which correspond to the similar accumulations occupying a like position in the plateaux of the north of France. Occasionally also beds of coarse sand appear on the same horizon, but they are of little extent, and occur for the most part in depressions or hollows. The lower portion of the löss-beds has all the characters of Rhenish löss. It is yellow in colour, unstratified, and more or less calcareous, and it shows the characteristic vertical capillary structure; it likewise contains land- and freshwater-shells of the usual species, such as *Helix hispida, Pupa muscorum, Clausilia laminata, Bulimus obscurus, Succinca oblonga,* etc. The upper portion, as just stated, differs from the lower in colour and composition. It does not effervesce with acids and is frequently plastic, which is not the case with the lower. The shells it contains are chiefly helices, such as *H. nemoralis, H. hortensis, H. lapicida,* and *H. rotundata.* According to the Belgian geologists this upper clay is distinguished by the presence of remains of the reindeer, while those of the mammoth occur in the lower or lössic portion. I may note also that Professor Malaise has recorded the discovery of Palæolithic implements under the löss in the neighbourhood of Spiennes, south-east of Mons.

M. Dupont, it will be remembered, has described the occurrence in certain caves in the province of Namur of clay with angular blocks. He likewise mentions the interesting fact that this stony clay is occasionally overlaid by löss, as in the following section, which gives the results obtained from an examination of several caverns :—[1]

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[1] *Bull. Acad. de Belg.*, 2e Sér. t. xx. p. 284.

1. Löss.
2. Yellow clay with angular fragments of limestone.
3. Stalagmite.
4. Argillaceous sand with thin layers of gravel.
5. Rolled stones, derived from the Ardennes.
6. Sand with peat.
7. Red clay.

The same geologist has correlated the deposits in the caverns with those which occur outside in the following manner:—

Exterior.	Caves.	Stages.
1. Löss with or without stones and blocks.	1. Löss with or without stones and blocks.	Upper or Reindeer Stage.
2. Yellow clay with blocks.	2. Yellow clay with blocks, with remains of reindeer, etc., flint implements, etc.	
3. Argillaceous sand, irregularly stratified, with intercalations of gravel and rolled stones ; calcareous concretions and land-shells.	3. Argillaceous sand, irregularly stratified, with intercalations of gravel and rolled stones ; calcareous concretions ; remains of cave-bear and flint implements.	Middle or Cave-bear Stage.
4. Gravelly sand with river-shells.	4. Traces of sand.	
5. Rolled stones with mammoth.	5. Rolled stones.	Lower or Mammoth Stage.
6. Gravelly sand.	6. Gravelly sand with peaty matter.	

The löss is thus of more recent date, it will be observed, than any of the other deposits with which it is associated in the caves. It occupies, in short, the highest level.

From the facts now adduced it is evident that the löss of Central and Western Europe cannot be considered as a separate and independent formation. We find it again and again closely associated with river-gravels, and containing intercalations of clay, sand, and stones. It is true that in the Rhine valley it retains a remarkably homogeneous character throughout a wide area, and a great thickness, and it is little wonder that geologists, whose theories of the origin of löss have been based chiefly upon the phenomena presented by that deposit in the larger valleys of Central Europe, should have held the view that löss is something quite by itself, having little or no connection with the other Pleistocene accumulations with which it is associated. But, as we have seen, in Belgium, and more especially in Northern France, it loses much of its typical character, and this is still better exemplified in the valleys and low grounds of the south of England, where the löss-beds are composed in large measure of brick-earth, in which sand, and even gravel, are frequently intercalated. In short, the volume and composition of the löss-beds are directly related to the extent of the drainage-areas in which these deposits occur, and to the geological character of the rocks from the degradation of which they have been derived.

Great as is the extent of area in Central and Western Europe, which is covered by löss and brick-earth, it is yet inconsiderable when compared with the vast tracts which in Southern Russia are clothed with the "Tchernozem" or black-earth—an accumulation which occupies the same geological horizon as the löss, and the origin of which is undoubtedly closely bound up with that of the former. The black-earth extends over the Steppes and low-lying plateaux that border on the Black Sea, the Sea of Asov, and the depressed area to the north of the Caspian, with a breadth from north to south of from 200 or 300 to nearly 700 miles. It may be said to continue with little interruption from the regions watered by the Pruth and the Dniester to the foothills of the Ural Mountains, between Ufa and Orenburg, thus comprising an area of not less than 500,000 square miles. Throughout this wide tract the black-earth shows a singularly uniform character. Like the löss of Central Europe, it has an extremely fine texture, and is usually devoid of well-marked stratification. It varies in colour from dark brown to black, and in thickness from a foot or two up to twenty, and occasionally, it is said, even to sixty feet.

According to analyses by Phillips, Daubeny, and Payen, which are given by Murchison and his eminent associates Verneuil and Keyserling,[1] the black-earth is composed of siliceous sand (about 70 per cent), alumina, and other mineral ingredients (23 per cent) and organic matter (about 7 per cent), the latter containing nearly 2·5 per cent of nitrogen. A nearly similar result was obtained by Hermann from three analyses, the amount of organic substances being 10·42 per cent.[2] Professor Gœbel some years before had analysed two specimens of black-earth from the neighbourhood of Saratov.[3] One of these yielded 22 per cent of combustible and vegetable ingredients, and the other 23 per cent, the former yielding 6·25 per cent, and the latter 14·5 per cent of humic acid. The other ingredients consisted chiefly of silica and alumina, etc., but while one specimen contained only 4·50 per cent of carbonate of lime, the other showed not less than 30·12 per cent. Murchison and his colleagues state that the black-earth is wholly unfossiliferous, not a trace of any organism, either plant or animal, having been detected by them. Gœbel, however, states that in subjecting one of his specimens to a mechanical separation he found, in one hundred parts, 9·7 per cent of stony ingredients with "coarse organic remains," and 90·3 per cent of fine sifted earth. The other specimen contained neither stony ingredients nor "coarse organic remains." Of the 9·7 per cent of coarse-grained matter, 4·19 was made up of vegetable *débris*, and 5·51 of clay. Unfortunately, Gœbel does not tell us from what depth the specimens were taken, but it is probable that they were obtained at or close to the surface : he describes them indeed as being "Ackerkrume" (mould).

According to Murchison, etc., the black-earth "occupies the centre of a trough, large as an European empire, having the detritus of the crystalline and older rocks for its northern, and the low granite Steppes and Caspian deposits for its southern, limits." It is found at all levels up to heights of 300 and 400 feet above the valleys. In some places it overlies ancient river-gravels, while along its northern limits it appears to rest upon, and now and then to be covered by certain accumulations which are known as "Northern Drift," and of which I shall speak farther on. Murchison and his associates state that the materials of this "drift," consisting of stones derived from the north, are reduced to small size, and mixed with the *débris* of local rocks as they approach the northern margin of the black-earth, by which deposit they are succeeded if not overlapped. At one place, however, they observed "erratics" or travelled stones of northern derivation superimposed on the black-earth.

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[1] *Geology of Russia in Europe and the Ural Mountains*, vol. i. p. 559.

[2] Cited by Bischoff, *Elements of Chemical and Physical Geology* (English edition, 1854), vol. i. p. 135. The reference there given is *Journ. für pract. Chemie*, Bd. xii. p. 290.

[3] *Reise in die Steppen des südlichen Russlands*, 1838, Bd. i., p. 297.

Many theories have been advanced in explanation of the phenomena presented by the various accumulations—the loams, loamy clays, löss, and black-earth—which we have now passed in brief review. The löss of Central Europe especially has given rise to many speculations, and will probably continue to exercise the ingenuity of geologists for years to come. At one time it was supposed to be of marine origin, a view advanced by Bennigsen Förder, but which has long been abandoned, and the lacustrine hypothesis in its various forms has shared no better fate. The earliest exponent of the latter was Hibbert,[1] who believed that the Rhenish löss had accumulated in a wide freshwater basin that formerly occupied the broad and open part of the Rhine valley above Bingen, prior to the time when the present outlet had been sufficiently deepened to permit any overflow in a northerly direction. The hypothetical lake was supposed indeed to have then drained to the south. After its bottom had received a great accumulation of fine mud, the Alps were, according to Hibbert, suddenly upheaved, and the drainage of the lake was thereby instantaneously reversed. The whole of its contents were now discharged in one enormous diluvial rush, and swept through the straits at Bingen, which were deepened as the

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[1] *History of the Extinct Volcanoes of the Basin of Neuwied on the Lower Rhine*, chap. xxv. For an account of the reversal of the drainage in that region, see an interesting paper on the origin of the valley of the Rhine by Prof. Ramsay *Quart. Journ. Geol. Soc.*, vol. xxx. p. 81.

débâcle passed; a large proportion of the muddy contents of the basin being carried far down the valley, and scattered over a wide area. Another view, suggested by Gümbel in his great work on the geology of Bavaria, endeavoured to account for the löss by a rapid melting of the extensive snow-fields and glaciers of the Alps, which was supposed to have taken place towards the close of the Glacial Period of geologists, and to have been induced by a sudden depression of the mountains. Vast volumes of water thus set free, descending in irresistible torrents and *débâcles*, strewed all the low grounds with sand and gravel, and soon forming a wide inland sea, allowed the deposition of fine mud (löss) to take place quietly and continuously. Sir Charles Lyell, on the other hand, was of opinion that the löss had been deposited as a fine alluvial silt by the present rivers at a time when their fall was considerably lessened by a gradual subsidence of the Alps. Their power of transporting sediment being thus reduced, much of the mud and silt which they formerly carried to the sea was now allowed to accumulate in the valleys themselves, and this process is supposed to have continued until the rivers had deposited a thickness of several hundred feet of löss—until, in short, wide valleys like that of the Rhine above Bingen had become well-nigh filled up. The Alps and the upper reaches of the valleys having become subsequently re-elevated, the rivers re-excavated their loams, and cleared out the basins which they had previously filled to repletion.

Each of the views now mentioned postulates the former occurrence of some movement of the earth's crust—a demand not in itself unreasonable if it otherwise satisfies all the conditions of the problem. But this is just what each of the theories fails to do. The geographical distribution of the löss and its associated deposits, and the elevation often attained by them above the valleys are fatal not only to every form of the lacustrine hypothesis, but also to the ingenious view supported by Lyell. A depression of the Alps and the surrounding regions would doubtless diminish the fall of the rivers that take their rise in those mountains, and cause them to accumulate much sediment in their valleys; but we have no reason to believe that löss ever filled up the valleys in the manner supposed. On the contrary, all the evidence goes to show that the accumulation in question is a mere superficial covering, spread over the surface of the ground, the original features of which it disguises but does not conceal. There is no proof that the Rhine valley was ever filled across its whole breadth, and throughout its entire length, from Basel say to its mouth, with a depth of 300 or 400 feet of löss. The löss is a mere envelope which cloaks the slopes of the valleys, and was probably never much thicker than it is now. Moreover, it is obvious that Lyell's theory will not account for the presence of löss in valleys, the drainage of which could not have been affected by any subsidence of the Alps. To explain the occurrence of löss in such valleys we should on the same principle be compelled to suppose that the Pyrenees, the plateaux of Central France, the Vosges, the Thüringer-Wald, the Erz mountains, and the Carpathians, had likewise been depressed with reference to the surrounding low grounds, and again elevated. And a similar inference would be necessitated for the limited and little elevated watersheds in the south of England. Nor would all these local movements of subsidence and re-elevation account for many considerable areas of löss, amongst which I may mention that narrow zone which extends in Northern Germany along the southern margin of the great "Northern Drift." It is likewise obvious that we should still have to account upon some other principle for the enormous development of the black loamy deposits of southern Russia.

There is one opinion upon which geologists are pretty generally agreed, namely, that the löss of the great valleys of Central Europe consists for the most part of glacial mud. It is believed to be the finely-levigated material derived from the grinding of glaciers upon their rocky beds, and transported to the low grounds by torrents and fluviatile action. And it is likewise admitted by most that this distribution of fine silt took place at a time when the mountain systems of our continent supported more extensive snow-fields and glaciers than are now met with in Europe. But as löss occurs in some valleys which do not appear ever to have contained glaciers in their upper reaches, the löss in such cases is believed to be the result simply of melting snow and a heavy rainfall. Mr. Tylor has indeed advanced the view that a Pluvial period accompanied and succeeded the disappearance of great snow-fields and enormous glaciers. Professor Prestwich, as we have seen, conceives the löss to be the result of river-floods commencing at the period of the highest valley-gravels, that is to say at a time when the present valleys were beginning to be excavated, and continuing down to the end of that of the lowest valley-gravel. Mr. Tylor, on the other hand, appears to be of opinion that both the gravels and the löss were laid down by vastly swollen rivers after the valleys had attained very nearly their present depth and breadth, and he would therefore draw no distinction as regards age between the high-level and low-level deposits. It is quite impossible, however, to conceive that any river-floods could have reached the enormous height which such an hypothesis demands. Professor Prestwich may have under-estimated the extent of the ancient floods, and my own observations have led me to believe in the former existence of inundations on a considerably more extensive scale than those to which he ascribes the formation of the loams of Northern France and the south of England; but all the evidence, so far as I am able to read it, appears to bear out his view that the hill-löss and high-level gravels, speaking generally, are of greater antiquity than the valley-löss and low-level gravels.

The late Mr. Belt advocated a view of the origin of löss which I believe was first suggested by my brother, Professor A. Geikie, who pointed out to Dr. Croll that the excessive accumulation of löss in the Rhine valley may have been due to the presence in the North Sea of a great *mer de glace* which may have impeded the egress of the rivers to the north and caused them to flood wide regions in the Netherlands. Mr. Belt went farther than this, and maintained the opinion that the advance of a great polar glacier or ice-sheet upon Northern Europe and Northern Asia blocked up the drainage of the rivers flowing to the north, and converted the low grounds of Northern France, Southern England, the Netherlands, Northern Germany, vast areas in Russia, and all Northern Siberia, into wide inland seas of fresh water, in which extensive deposits of silt took place —an opinion which does not appear to have met with any support. It is in fact contradicted by the evidence of the löss itself —the distribution and character of which refuse to be so explained. Nevertheless, it is highly probable that the European rivers flowing north actually were impeded by the presence in those regions of a great ice-sheet, as I shall point out in succeeding pages. But whether that obstruction gave rise to the löss of Central Europe is another question. Be that, however, as it may, it is certain that vast deposits of löss have been formed in regions where no such damming of the rivers can be supposed to have taken place. The great löss-deposits of the Missouri and Mississippi, for example, certainly cannot owe their origin to the ponding back of those rivers by glaciers. Neither can we account for the presence of the Russian "Tchernozem" by any such hypothesis. Murchison and his colleagues maintained that the black-earth was accumulated in the sea by diluvial currents sweeping from the north — a view which does not receive support from the occurrence of any marine organic remains. In whatever manner it may have been formed— whether in the sea or in fresh water—it is clear that neither currents nor rivers could have been dammed back as Belt supposed was the case with the rivers of Northern Europe and Siberia.

M. de Mercey, after having for some time upheld the theory of the "diluvial" origin of the *limon* of the plateaux of the north of France,[1] has of late given up that view and advocated a very different one.[2] He is now of opinion that the lower portion of the *limon* (*limon biéfeux* or *limon grossier*) is of glacial origin, and that it indicates the former existence in the north of France of an ice-sheet like that which covers Greenland. In proof of this he points to the fact that the *limon biéfeux* is abundantly charged with angular fragments of flint, besides a number of whole flint-nodules. But these last are so much cracked and fissured internally, that they generally fall into pieces while they are being extracted from the loam. Their cracked condition he attributes to the action of frost, and as they now lie buried beyond the influence of atmospheric changes, he infers that they must have been split by frost at the time of their entombment in the *limon*. Again, the loam which encloses them is composed of very unequally-sized grains, which he thinks could not have been deposited at one and the same time by water. Had the *limon* been an aqueous accumulation, he believes that the coarser and finer granules would have been laid down at different times and in different places. The upper part of the deposit (*terre à briques*), on the other hand, is composed of uniformly-sized grains, and is thus in his opinion the result of aqueous levigation. It owes its origin to the washing and re-arranging of the *limon biéfeux*. The latter, he thinks, was accumulated in the state of clay, and along with the broken flints was formed by the action of frost and ice. It has been derived from the destruction of the rocks upon or near to which it occurs, and changes its character as these change theirs. M. de Mercey then points out that the flint-bearing loam presents a very irregular surface of contact with the rocks upon which it reposes—this surface being quite unlike one which aqueous erosion would have produced. The Chalk and other strata have been irregularly trenched and excavated, so that the loam descends ever and anon into pockets and cavities. Again, he shows that the stony loam spreads like a sheet over the surface of the rocks, and is not disposed in terrace-shaped accumulations. It follows all the undulations of the ground—covering hollows, slopes, and elevations alike. He alludes further to the form of the ground, which frequently presents the appearance of parallel ridges and intervening hollows, of a character which betokens some other mode of origin than that of erosion by the waters either of the sea or of violent inundations and *débâcles.* In his opinion only glacier-ice could have produced the peculiar contour to which he refers. The *limon biéfeux,* he concludes, is a true glacier-mud which has been formed underneath ice and left lying upon the surface at the time when the glaciers or ice-sheet melted away. It is essentially of local origin, and in its composition always reflects the character of the strata in the immediate neighbourhood of which it occurs. The *limon biéfeux* of Picardy, according to M. de Mercey, corresponds to the yellow clay with stones and blocks which M. Dupont has described as covering certain regions in Belgium. The overlying brick-clay he would assign, as already mentioned, to the subsequent action of water, etc., washing, sifting, and re-arranging the materials of the *limon biéfeux.*

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[1] *Bull. Soc. Géol. France*, 2e Sér. t. xxii. pp, 75, 76, 84, 102.

[2] *Bull. Soc. Linn. du Nord de la France*, t. ii. p. 334.

M. de Mercey's views have been controverted at considerable length by M. E. d'Acy,[1] who maintains that both the lower and the upper loams of the north of France are the result of a great diluvial cataclysm, as M. Belgrand has maintained,[2] and that this cataclysm took place in Pleistocene times and after the valleys had been excavated. He appears to me to have shown that Mercey's contention that the *limon biéfeux* is of the nature of a *moraine profonde* or *subglacial mud* is hardly well supported, but he has not satisfactorily disposed of the evidence which, as M. de Mercey has indicated, goes to prove that the *limon biéfeux* was accumulated under cold conditions of climate. But to this point I will return in the sequel.

An entirely novel view of the origin of löss has been advanced by Baron Richthofen, and amply illustrated in his great work on China. A deposit similar in all respects to the Rhenish and Danubian löss covers vast areas in that country. It differs from the löss of Europe only in its greater vertical and horizontal extent. Richthofen describes it as forming cliffs or bluffs on the Yellow River, which in some places rise to a height of

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[1] *Le Limon des Plateaux du Nord de la France et les silex travaillés qu'il renferme* (1878).

[2] *La Seine, I. Le Bassin Parisien aux Âges Antéhistoriques,* p. 216; *Compt. Rend. Congr. Intern. d'Anthrop.,* etc., Bruxelles (1872), p. 131.

500 feet. In many places, he says, it reaches a thickness of 1500 feet. It extends inland over all the high plains, from the alluvial flats of the Gulf of Tshili over the Taihhang-shan Mountains up to plateaux 1800 mètres high, and even to an elevation of 2400 mètres above the sea in the Wu-tai-shan Mountains in Northern Shansi. It stretches south of the hilly grounds beyond the valley of the Yangtze, and up that valley in a westerly direction for an unknown distance. It can be followed up the course of the Han to the watershed of that river, and it is known to extend up the valley of the Yellow River without interruption into the province of Kansuh. This enormous deposit, according to Richthofen, is solely the result of atmospheric waste and wind-action; and he has brought forward a large body of interesting and important evidence to prove the correctness of his theory.

The winds that blow across a great continent like Asia are to a large extent drained of their moisture by lofty mountains, elevated plateaux, etc., before they can reach certain regions in the interior, which as a consequence become desiccated and deprived of springs and rivers. The materials which are the result of atmospheric waste, and which in well-watered regions would eventually find their way to the sea, are allowed to accumulate upon the surface of such dry desert areas, and the rocks, bared of their vegetable covering, crumble away, more or less rapidly, to loose grit and sand. Occasional rains and torrents help to carry the products of superficial waste down to the lower grounds, where they become still further reduced in size, and are sifted by the action of the wind. Vast quantities of dust and fine sand are thus produced, and during storms these are swept up and scattered over extensive areas, and in this manner adjoining territories, such as the grassy steppes, are ever and anon receiving increments to their soil. The finely-sifted material thus obtained is highly fertile, and offers no impediment to the growth of the grasses, which, on the contrary, continue to flourish; and so every addition brought by the winds becomes in this way fixed, and the Steppe-formation goes on increasing in thickness. It is this continual growth of the grasses, keeping pace as it were with the periodical accumulation of soil, which, according to Richthofen, produces that peculiar porous capillary structure which has been described above as characteristic of typical löss. He also insists upon the fact that the organic contents of the Chinese löss pertain exclusively to terrestrial forms—to land-shells and land-animals—the remains of which occur at all depths in the accumulation.

As the shells met with in the Chinese löss belong exclusively to living species, and the deposit is unquestionably of a recent geological age, this theory of its origin implies an amount of atmospheric disintegration and wind-transport and accumulation which it is hard to conceive could have taken place within the time required. Nor is this difficulty much lessened if we allow with Professor Pumpelly that the materials of the löss had already been prepared for the wind during the lapse of long ages by the action of rain and rivers, frost, snow, and ice; so that all the wind has done has been merely to redistribute alluvial and other similar materials, and to remove the loose insoluble products of a previously long-continued disintegration of the rocks. It may be that we have hitherto underestimated the action of winds as geological agents in dry continental areas like those of Central Asia, and that aerial currents have played a much more important *rôle* in the past than has been generally supposed. "No one," Mr. Pumpelly remarks, "can realise the capacity of wind as a transporter of fine material who has not lived through at least one great storm on a desert. In such a simoom the atmosphere is filled with a driving mass of dust and sand, which hides the country under a mantle of impenetrable darkness, and penetrates every fabric; it often destroys life by suffocation, and leaves in places a deposit several feet deep."[1] But such rapid accumulation occurs, I presume, only in the desiccated desert itself or its immediate neighbourhood. Deserts of shifting sand increase their bounds by a gradual encroachment, the dunes of the peripheral regions continually advancing in the direction of the prevailing winds. The lighter dust, which is carried on the wings of the wind and frequently transported for distances of several hundred miles, leaves but a slight film upon the surface of the ground where it falls. And if this be so, one cannot but be amazed at the length of time required for the subaerial sifting of material, and for the transport from the dry central regions of Asia of that finest dust with which so large a portion of China eventually became covered to a depth varying from 50 or 100 feet up to 2000 feet. There are many other difficulties that seem to stand in the way of Richthofen's theory of the origin of the Chinese löss, but these need not be urged;[1] and we may well admit that the accumulations so admirably described by him in his beautiful work have been very considerably modified by the action of winds. But however satisfactory his theory may be as an explanation of the löss of China, it appears to me to be quite inapplicable to that of Europe. Our loamy accumulations refuse, as I believe, to be so explained. My reasons for thinking so I shall venture to bring forward; but before doing so, and in order to carry my reader with me, I must first give a rapid outline of the principal features of that remarkable epoch in the world's history which geologists speak of as the Ice Age or Glacial Period.

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[1] *American Journal of Science and Art*, vol. xvii. (1879), p. 139.

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[1] M. l'Abbé David has stated his objections to the theory in question.—See *Journal de mon troisième voyage d'exploration dans l'Empire Chinois*, t. i. p. 94; and Mr. Kingsmill has likewise combated Baron von Richthofen's views. (See *Quart. Journ. Geol. Soc.*, 1871, p. 376; *The Border Lands of Geology and History:* an Inaugural Address, delivered to North China Branch Roy. Asiat. Soc., 1877). In place of the wind-theory Mr. Kingsmill will have it that the Chinese löss is a marine deposit, a view which seems on the face of it as difficult of belief as that which he opposes.

CHAPTER X.

THE GLACIAL PERIOD.

Early views of glacial phenomena—Agassiz's glacial theory—Glacial phenomena of Scotland—Origin of rock-striæ, *roches moutonnées*, till or boulder-clay, etc. —Intruded till and great erratics—Direction of glaciation in Scotland—Glaciation of Ireland; of English Lake District; of Lancashire; Wales, etc. —Glacial phenomena of north-east of England; of Midland districts and East Anglia—Great erratics—Glaciation of Norway and Sweden; of Finland and Northern Russia; of Germany—Contorted and disturbed rocks under boulder-clay—Great erratics—Direction of the northern *mer de glace*—Course followed by "under-tow" of ice-sheet.

THROUGHOUT vast areas in the low grounds of Northern Europe, and in all the mountain-tracts of the central and southern regions of our continent, we encounter the clearest and most abundant evidence to show that a much severer climate than the present has formerly obtained. I have already adduced a number of facts which must have convinced the reader that towards the close of the Palæolithic Age the ancient inhabitants of Aquitaine lived under conditions such as now characterise only the higher latitudes. When the temperature in Central and Southern Europe was so depressed as to allow reindeer and musk-sheep to live in the low grounds that sweep north from the base of the Pyrenees, and the glutton, the marmot, and the tailless hare to frequent the shores of the Mediterranean, what, we may well ask, must have been the condition of those tracts to which these animals are now restricted? Fortunately we are able to give a very definite reply to this question. The evidence brings before our vision scenes that are in strangest contrast to the present—

vast regions of Northern Europe buried under perennial snow and ice, huge glaciers deploying upon the low grounds of France and Italy, and creeping down the mountain-valleys of southern Spain ; ice, in like manner, choking the upland valleys of Corsica ; snow-capped mountains everywhere. Cold currents flowing out of the Polar Ocean then laved the shores of North-western Europe, bringing with them many arctic forms of life, which occupied the area vacated by the temperate species as these last found their way south to the coasts of Spain and the Mediterranean. The walrus, now one of the rarest visitors to Ultima Thule, frequented the English Channel,[1] where ice-rafts were common, and into which rivers, flowing from perennial snow-fields and glaciers, discharged their muddy waters.

To give an adequate description of the facts upon which these conclusions are based would lead me far beyond the scope of this work, and I can find space for only a meagre outline of the subject. The history of the Glacial Period or Ice Age is read in certain peculiar markings upon rock-surfaces ; in the configuration of hills, the form of valleys, and the multitude of lakes in alpine and northern regions ; in the character of certain superficial accumulations of clay, gravel, sand, boulders, and *débris,* which in those regions are more or less abundantly developed ; in the presence of arctic and boreal shells and other marine forms in the clay-deposits of low latitudes like our own ; in the appearance of high-alpine and hyperboreal plants in ancient peat-bogs ; and finally, in the present distribution of the flora and fauna of Europe. These phenomena and the mode in which they are interpreted have been discussed somewhat fully in the work mentioned below,[2] to which the reader who wishes to study the subject in detail may refer. The general results arrived at are all that I can attempt to give in this place.

The more conspicuous traces of the great glaciers and seas of ice which formerly existed in Europe, are so prominent that they had long excited wonder before any serious attempt was made to account for them in a natural way. Numerous are the myths and legends connected with the great boulders of our own country. They are the "giant's putting-stones," the "deil's burdens," the "witch's hearth-stones," of the fanciful peasantry. Zealous antiquaries have occasionally claimed them as monuments set up by man in some long-forgotten age. In later times they have been ascribed by serious observers, amongst others by Deluc, to the underground forces of nature—the shattered fragments resulting from the explosion of imprisoned gas. Others again have attributed them to the action of sudden torrential floods, pouring in vast volumes down mountain-valleys to the low grounds—a view which was speedily abandoned when the distances which the boulders must have travelled came to be better known. The enormous size attained by many of the blocks was also a difficulty which this hypothesis could not remove. It was found, for example, that some of the great boulders lying upon the slopes of the Jura, and which had come from the upper reaches of the Rhone valley, measured upwards of 10,000 cubic feet. The famous Pierre à Bot, above the Lake Neuchâtel, is a block of granite estimated to weigh 1500 tons. It is needless to say that there is no river which could possibly move masses so enormous as these. The very general distribution of erratic blocks by and by suggested another explanation of their origin. They had been traced across nearly the whole breadth of Northern Europe, from Holland to St. Petersburg and Moscow—they swarmed upon the low grounds bordering on the Baltic,—they were hardly less abundant in Middle Germany, they were sprinkled plentifully over Scotland, Ireland, and a large part of England. Their occurrence in the alpine regions of Switzerland and the Pyrenees was notorious, and they had been observed also as far south as Granada. The general directions in which they had travelled had likewise been ascertained. Thus it was known that many of the large blocks scattered over the surface of Northern Germany had been derived from

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[1] See a paper by M. G. A. Defrance, *Bull. Soc. Géol. France,* 3^{e} Sér. t. ii. p. 164.

[2] *The Great Ice Age,* etc., 2d ed.

Scandinavia. The underground forces had been found altogether insufficient to account for those phenomena, and the idea of enormously-flooded rivers had likewise failed to afford an adequate solution of the problem. The next theory was that of deluges or inundations which were supposed to have swept over the Continent. This view was ably supported by the well-known experimental geologist Sir James Hall, who, after carefully exploring the neighbourhood of Edinburgh, concluded that the direction of the *débâcle* in Central Scotland had been from west to east. No one can read Hall's interesting descriptions without being impressed with his penetration. He was not content merely with tracing out the trend taken by the stones, but he was the first to show that the markings on the rocks had been produced, and that the prominent features of the land itself gave evidence of having been greatly modified, by some force coming from the west. Similar observations carried on in other regions with as much care and intelligence as Hall bestowed upon his work, could hardly have failed to anticipate the theory with which the name of Agassiz is now indissolubly associated. As it was, they soon effected the demolition of the very view in support of which they had been adduced. The great difficulty was how to account for such deluges. Some were of opinion that the inundation was universal, and had its origin in the far north, from which a series of great waves were precipitated over Europe, sweeping large blocks and *débris* and everything before them. Others again, who knew that all the erratics had not travelled in one and the same direction, thought that instead of one great deluge there had been a number of smaller but still powerful irruptions of water. But where did the water come from? Some said from the sea, others, such as Lamanon and Sulzer, from lakes which had burst their barriers. But where had those lakes existed, the bursting of which could have scattered Scandinavian boulders broadcast over Denmark, Holland, and all Northern Germany? And how had the sea been compelled suddenly to forsake its bed and sweep in giant waves across the Continent? It was vaguely suggested that perhaps some mighty earthquake-shock or sudden upheaval of a mountain-chain, or of the sea-bottom, had been the cause of the deluges. Few, however, had the boldness to enter into particulars, and in this respect they were more cautious than Pallas, who, in order to account for the presence of bones, tusks, skeletons, and carcasses of elephants, in the alluvial deposits of Northern Siberia, had made the extraordinary suggestion that a tremendous *débâcle* might have swept them north from India—a *débâcle* which he attributed to the great eruptions that had produced the Moluccas, Philippines, and other islands of volcanic origin in the Indian Ocean. But we must remember that a century has elapsed since Pallas wrote, and his theoretical notions, however wild they may appear to us, would not seem so to his contemporaries. In the many "theories of the earth" which were current in his time, one may read of still more startling hypotheses. We are told, for example, by St. Pierre, that the Deluge was caused by the simultaneous sudden melting of two vast and towering cupolas of ice that covered the Poles, the waters from which, rushing in two enormous *débâcles* from north and south, overwhelmed all the low grounds of the world. "Complete islands of floating ice," he says, "loaded with white bears, ran aground among the palm-trees of the torrid zone, and the elephants of Africa were tossed amidst the fir-groves of Siberia, where their large bones are still found to this day." At a more recent date we encounter another curious view advanced by the celebrated French geologist, Elie de Beaumont, who accounted for the transport of erratic *débris* from the Alps by means of enormous currents derived from the sudden meltings of the snows upon the lofty heights of the Eastern Alps—"qui ont dû être fondues en un instant par les gaz auxquels est attribuée l'origine des dolomies et des gypses."[1] This strange notion also commended itself to Collegno, who endeavoured by similar means to explain the glacial phenomena of the Pyrenees.[2]

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[1] *Sur les Revolutions de la Surface du Globe*, p. 285.

[2] *Ann. des Sci. Nat.*, t. ii. p. 191 ; *Bull. Soc. Géol. France*, 1^e Sér. t. xiv. p. 402.

It was not until Agassiz visited Scotland and pointed out the evidence for the former existence of glaciers in that country[1] that British geologists were put upon the right scent. For some years before this time, however, it had been ascertained that a cold climate had prevailed in Scotland during a very late Tertiary period. The late Dr. Thomas Thomson had discovered and described those beds of fossil mollusca on which so much of the evidence of the Glacial Era depends, and four years later appeared the first of a series of well-known papers by Mr. Smith of Jordanhill, in which the same phenomena are discussed, and an allusion made to Thomson's discovery.[2] After this time our knowledge of the glacial phenomena, thanks to the labours of Buckland,[3] Lyell,[4] J. D. Forbes,[5] Maclaren,[6] Chambers,[7] and others, rapidly increased. The theory of *débâcles* was laid aside, but a belief that a large part of the phenomena could only be accounted for by enormous submergences of the land continued for many years to hold possession of geologists, and still lingers on amongst some observers whose attention has perhaps been too exclusively confined to the low grounds of England. But the notion of "waves of translation" has long disappeared. Those who still cling to the view that much of the clay with far-travelled stones which covers such wide areas in the lowlands of Britain and the Continent is of marine origin, readily admit the former existence of glaciers in the hillier regions; but they maintain that a large proportion of the erratics and stony clay has been distributed during a period of submergence through the agency of floating-ice. It is not my intention to combat this view here; it has already, as I believe, received the *coup de grâce* at the hands of many glacialists,[1] British and foreign, and may be allowed to die in peace. It has been abandoned in Switzerland, where all the phenomena of glaciation are so well developed; it has become equally extinct in Scandinavia. In our own country, notwithstanding our insular position and supposed affection for the sea, its supporters are rapidly diminishing in number; and of American observers the same tale may be told. I would not have the reader to suppose, however, that modern glacialists have discarded the notion that any part of the land during the Glacial Period was submerged, or that they refuse to believe that any of our erratics have been transported by floating-ice. On the contrary, the evidence that large areas have been submerged is overwhelming, and not a few erratics occur at low levels in our maritime regions which there is every reason to suppose have been carried there by ice-rafts. But the more salient features of the phenomena, such as the rounded rocks, the smoothed, polished, and striated surfaces, we do not believe icebergs had any share in producing; and they are just as inadequate to explain the formation and distribution of those vast sheets and mounds of stones, clay, gravel, sand, and erratics, of which I shall speak by and by.

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[1] *Proc. Geol. Soc.*, vol. iii. p. 327; *Edin. New Phil. Jour.*, vol. xxxiii. p. 217.

[2] See Obituary Notice of Dr. Thomson by Sir Joseph Hooker, *Journ. Royal Geogr. Soc.*, vol. xlviii. p. cxxxvii. Thomson's paper appears in *Records of General Science*, vol. i. p. 131, February 1835. Glacialists are indebted to Sir Joseph Hooker for calling their attention to this paper, which has been quite overlooked.

[3] *Proc. Geol. Soc.*, vol. iii. pp. 332, 345; *Edin. New Phil. Journ.* vol. xxx. pp. 194, 202.

[4] *Proc. Geol. Soc.*, vol. iii. p. 337; *Edin. New Phil. Journ.*, vol. xxx. p. 199.

[5] *Edin. New Phil. Journ.*, vol. xl. p. 76.

[6] *Ibid.* vol. xl. p. 125; vol. xlix. p. 333; *Brit. Assoc. Rep.*, p. 90; and other papers.

[7] Many papers in *Edin. New Phil. Journ.*, *Brit. Assoc. Rep.*, and *Proc. Royal Soc. Edin.*, from 1850.

The spoor of the old glaciers, which formerly existed in the British Islands, has been followed successfully by a large band of enthusiastic observers, and the results they have come to are certainly, when baldly stated, enough to take one's breath away. But however astonishing they may seem to those who hear of them for the first time, they are yet based upon abundant facts which are not local or confined only to a few isolated areas, but general throughout all Ireland, Scotland, and a large portion of England. Neither are these facts such as can be explained in various ways. They lead only to one conclusion, and, as a recent writer has remarked,[1] "correspond so wonderfully in every detail to this conclusion, and this only, as to amount to absolute demonstration." Among the most remarkable phenomena are the smoothed and scratched rock-surfaces which are so common a feature in upland-valleys, and which are met with again and again upon hill-tops and hill-slopes, and on many exposed rocks in the low grounds. These markings agree precisely, even to the smallest minutiæ, with the similar appearances which have been observed underneath the overhanging sides of a glacier, and they are familiarly known upon the bottoms and flanks of every valley in the Alps, and many other regions which still support glaciers. No one doubts that such smoothed and striated rocks as one sees in the valley of the Unter Aar glacier and in the neighbourhood of the Grimsel, were produced by the grinding action of that glacier during some period of the past when it attained much larger proportions. The striae are engraved by the stones and grit which are rolled forward under the ice, and the rocks receive their smoothed and polished surface from the finer material—the sand and mud—which results from the grinding process itself. It was his familiarity with these facts, and his knowledge that the glaciers of Switzerland had in ancient times extended far beyond their present limits, which enabled Agassiz to discover the true meaning of the so-called "diluvial" phenomena in Scotland. Another feature which receives an equally satisfactory explanation is that of the rounded or mammillated rocks of our country. These correspond exactly to the *roches moutonnées* of Swiss geologists, so called from their having a fancied resemblance, at a distance, to sheep lying down. One sees that they have been produced by some heavy body passing over them in a determinate direction. They represent what must once have been rugged tors and knobs and angular excrescences, which the abrading action of a glacier has softened down. Where they have not suffered too severely from the influence of the weather they exhibit parallel striæ, ruts, and grooves, often in great perfection. It is also easy to tell from them in what direction the ice has moved; for it is the side facing that direction which shows the most marked glaciation, and which, in allusion to the severe abrasion it has experienced, is called by the Swiss geologists the *Stossseite* (lit. pushing- or thrusting-side). The leeside (*Lee-seite*) of *roches moutonnées* is generally less rubbed and worn, and, in many cases, is even quite rugged and free from glacial markings. Standing at the head of a valley in the Scottish Highlands and looking down, the hill-sides on either hand present a somewhat smooth and undulating surface, an appearance which vanishes when we walk down the valley and then turn to look back. The rocks which seemed rounded off when we viewed them from the upper reaches of the valley, now assume a much more broken and rugged aspect, a phenomenon which must be attributed to precisely the same cause as that which produced the planed and striated surfaces and the *roches moutonnées.* The observer in such a mountain-region soon becomes aware also of another appearance which is sufficiently remarkable. In some of our higher mountain-valleys he sees the striated rocks and the smoothed hill-slopes extending for a considerable distance upwards until they reach a certain elevation, above which the mountains show no traces of abrasion, but all is harsh and severe. Reflecting upon these facts, he concludes that the valleys have been at some period filled to a less or greater depth with ice, which flowed down towards the low grounds, smoothing and striating the rocks, removing asperities, and producing *roches moutonnées* after the very same manner as the glaciers of Switzerland and Norway. And by measuring the height to which the glaciated rocks extend, he is enabled to form an estimate of the thickness attained by the ice. By following out similar observations, we have now not only ascertained the thickness of the ice and the direction in which it flowed, but we have also acquired some definite notion of the degree at which its upper surface sloped away to the horizon.

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[1] See Ramsay, *Old Glaciers of Wales; Quart. Journ. Geol. Soc.*, vol. xviii. p. 202; Jamieson, *Quart. Journ. Geol. Soc.*, vol. xviii. p. 164; vol. xxi. p. 162; A. Geikie, *Trans. Geol. Soc., Glasgow*, vol. i. pt. ii.; Croll, *Climate and Time*, p. 273; Dana, *American Journal of Science and Art*, 1873; *Manual of Geology*, 2d ed., p. 534. For other references see *Great Ice Age*.

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[1] *Quarterly Review*, July 1879, p. 229.

All the valleys of the Highlands and Southern Uplands of Scotland are now known to have contained glaciers. It is further known that those glaciers attained so great a thickness that in many cases their upper strata overflowed the limits of the valleys, and became confluent across the summits of the intervening high grounds, which are striated in precisely the same manner as the lower slopes. These unmistakable glacial markings have been traced up to a height of more than 3000 feet, and the general evidence shows that during the climax of the Ice Age only the highest hill-tops projected above the level of the great sheet of ice which overwhelmed all the mountainous regions of the country. More than this, glacial striæ, furrows, and *roches moutonnées* have been traced throughout all the lowland districts, and the trend of these indicates, in a manner not to be mistaken, that the districts referred to have been ploughed over by glacier-ice coming from the more elevated tracts of the country. And the thickness of that ice may be inferred from the fact that isolated hills and hill-ranges, such as the Sidlaws, the Ochils, the Lomonds, the Pentlands, the Campsies, and the rolling trappean uplands of Lanarkshire and Ayrshire, are glaciated up to and across their highest summits. All Scotland, in short, was enveloped in ice, which levelled up the valleys, so that its higher strata were enabled to grind across the tops of hills that rise to within heights of 2000 and 3000 feet above the present sea-level. Now it is evident that a mass of ice so thick as that could not float off in shallow seas like those which immediately surround us. We might have expected, therefore, to find that the islands lying off our coast should afford some trace of glacial invasion. And such is actually the case. The island of Bute, for example, has been overflowed from end to end by ice streaming out from the mountain-land of Argyleshire. Colonsay, in like manner, disappeared underneath the glacier-ice that choked up the Firth of Lorne—in a word, not one of the Western Islands escaped. Even the Outer Hebrides were swept across by the massive *mer de glace* that pressed outwards to the ocean.

The markings upon the rocks show us that, although all the hilly district of Central Scotland, and every island, were thus smothered in ice, they yet greatly influenced the direction of the ice-flow. As we approach some prominent hill that stood fronting the glacial current, we find the striæ begin to change their direction, bending round as it were to escape the obstruction. These hills and the smaller islands appear thus to have played much the same part as large submerged boulders in the bed of a river. They turned aside the ice that beat against them, buried deep though they were beneath the upper surface of the *mer de glace.* It must be remembered that it is not only level or approximately level surfaces which bear the marks of glacial abrasion. Sloping faces and sometimes even vertical faces are distinctly striated by ice which has been pressed up and over them. Thus the flanks of the Sidlaws and the Ochils, which look towards the Highlands, are grooved and striated by ice which has crossed Strathmore and Strathearn respectively, and thereafter made its way up and over both ranges, forced forward by the ice continually advancing from behind. The direction taken by the ice, therefore, does not always coincide exactly with the configuration of the ground—minor features such as those I have mentioned were practically disregarded, although as already remarked they always influence the trend of the striæ in a greater or less degree. The ice streamed out in all directions from the dominating ridges, and thus followed the line of what is still the main drainage of the country. For example, the general direction in the lowlands of Forfar, Perth, and Stirling was towards the south-east. In Linlithgowshire and Midlothian it is more easterly. The *mer de glace* from the Highlands encountered that which pressed northwards from the Southern Uplands, and thereafter the two streams united to flow east by way of Linlithgow, Midlothian, and Haddington, and south-west across the district that extends from the Clyde, near Hamilton, to the sea at Ayr. Deflections of the main current were thus produced by the conflicting motions of the great *mer de glace* itself. The most remarkable deflection of the kind, however, still remains to be noticed. But the evidence for this will be better appreciated after I have said something about the most important member of the glacial deposits—the *Till* or *Boulder-clay.*

The grinding of this enormous mass of ice, exceeding 3000 feet in its deeper parts, resulted in the general smoothing away of asperities and sharply-projecting rocks. And the result is seen now in the flowing contour which distinguishes all the hill-ranges of Central Scotland, the greater portion of the Southern Uplands, and all but the loftier peaks and ridges of the Highlands and mountainous islands of Arran and the Inner and Outer Hebrides. As a consequence of all this erosion and abrasion, immense quantities of stony *débris* gathered underneath the ice, and were slowly dragged and rolled forward. In the glacier-valleys of the Alps and Norway similar *débris* forms below the ice, but since a good deal of water circulates between that ice and the rocky pavement over which it flows, the finer sediment—the sand and mud—is washed out and carried away by the discoloured rivers that leap out at the terminal fronts of the glaciers. That similar streams and torrents and rivers flowed underneath the old *mer de glace* of Scotland admits of no doubt, for their water-worn gravel and shingle are here and there conspicuous enough in the heart of the glacial deposits. There appear even to have been what we might call sub-glacial lakelets—hollows underneath the ice in which fine clay slowly accumulated, and into which now and then stones were dropped from the over-arching roof of ice. But such streams and lakes probably bore a smaller proportion to the area covered by the ice than the rivers and lochs of the present land-surface do to the dry ground over which they are distributed. And consequently the coarse *débris* and clay and sand were allowed in most places to accumulate undisturbed by the modifying action of water. The stones which were in this way forced along underneath the ice came in time to have their angles rubbed off, and their faces smoothed, striated, and polished. The accompanying illustration (Fig. 5), which is drawn from nature by my friend Mr. B. N. Peach, represents a typical boulder-clay stone. It will be observed that the stone is smooth, and scratched principally

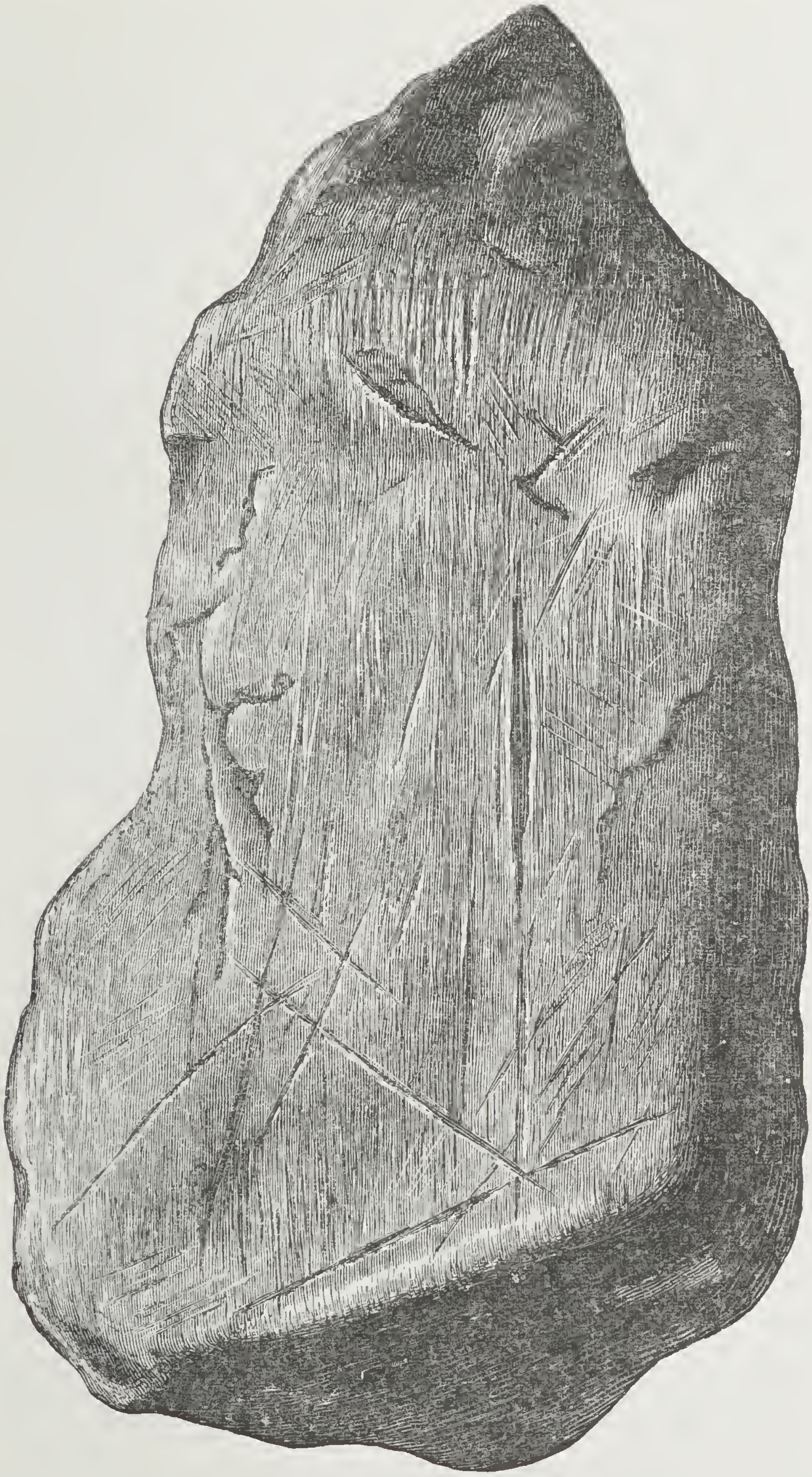

Fig. 5.—Striated Stone from Till or Boulder-clay.

in the direction of its length. This is most usually the case with stones that are decidedly longer than they are broad. When they come to measure much the same in all directions, then the striæ follow no particular trend, but cross and recross each other at all angles. The reasons for this are obvious; the stones which were being dragged forward under the ice would naturally arrange themselves in the line of least resistance, and this, in the case of the specimen here figured, would be lengthways. Now and again, however, such a stone would be turned over and get scratched to some extent in other directions. Stones that had no particular shape would not of course travel more easily in one position than another, and hence their irregular striation. The boulders seem to have received their finer polishing from being squeezed forward in the clay, which acted upon them like emery. And doubtless the pavement over which the stony clay was dragged was smoothed and polished by the same agent. Not only hard rocks like granite, but even soft black shales, which one may scratch with one's finger-nail, have been rolled forward in their matrix of clay, and in this position have acquired a finely-smoothed surface upon which one may detect striæ as delicate as the hairs of a pencil-brush.

Now, if boulder-clay has been formed in the manner I have thus briefly described, we might expect that its origin should be clearly shown by the mode of its distribution, by its colour, and by the direction in which it has travelled. In rugged mountain-glens, and on steep hill-slopes and hill-tops—wherever, indeed, the ice moved with a quicker motion than it could in broad straths and upon the open Lowlands, we should certainly not meet with till in any quantity. It should also be absent, or sparingly present, in all positions where, from the configuration of the ground, there must have been enormous force exerted by the ice. Thus, at the base of a steep hill fronting the direction from which the ice flowed, there should be little or none—for the same reason that sediment gathers sparingly in front of a boulder in the bed of a stream. But in the rear of such a hill as I speak of, it is clear that, if our theory be true, there ought to be a more or less considerable accumulation of glacial *débris*, just as we expect to find gravel and sand heaped up in the lee of boulders and submerged rocks in streams and rivers. Again, it is evident that in great valleys like the basin of the Forth, and wide spaces like Strathmore, and the low-lying districts generally, the ice would have a sluggish motion, and would, in such places, tend to accumulate subglacial *débris* to a much greater extent than in regions where the slope of the ground was considerably greater. All these expectations we find fully realised throughout the length and breadth of Scotland,—the till is distributed exactly as it ought to be, upon the supposition that it marks the bottom-moraine of an old *mer de glace.* And, what is still more suggestive of its origin, it is frequently arranged in the form of long broad smoothly-outlined ridges or "drums" and "sow-backs," as they are called, the trend of which exactly coincides with the direction of the striæ upon the underlying rocky pavement. These drums are especially conspicuous in the lower reaches of the Tweed in Roxburghshire and Berwickshire, and are well brought out upon the shaded one-inch map of the Ordnance Survey. The Drums of Nithsdale are also a fine example of the same phenomena. No one, however ignorant of glacial geology, can look at those maps without feeling convinced that the whole region has been acted upon by some great agent moving in one and the same determinate direction. In Teviotdale and Tweeddale all the ridges, whether of boulder-clay or solid rock, are seen sweeping down the main valley in exactly parallel lines. Here and there are prominent hills shooting abruptly upwards, each showing a steep face towards the region whence the abrading force moved, but sending out a long and narrow sloping bank of detritus behind. The drums bore the same relation to the old ice-sheet that the long ridges of gravel and sand in the bed of a river do to the current that heaps them up and is continually modifying them.

That boulder-clay consists of the *débris* of the rocks is sufficiently evident. The stones are the more or less worn and abraded fragments which have been detached during the grinding of the ice and the slow rolling-forward of its bottom-moraine. Many of these fragments have been carried a long distance; others have not travelled so far; while frequently we may see blocks lying quite close to the parent mass from which they have been wrenched. I have described the rocky pavement over which the ice flowed as often showing a planed, smoothed, and striated surface. In many cases, however, we find, instead of all this planing and polishing, only a jumbled accumulation of large blocks and broken *débris* under the till. The bed-rock has been smashed and crushed, and large masses have been pushed out of place, the boulder-clay often appearing tightly rammed between the blocks. This frequently characterises much-jointed rocks, like certain sandstones and igneous rocks. And one can see that the dislocated fragments have been dragged along in the same direction as that followed by the trend of the glacial striæ and drums of till in the same neighbourhood. Here we observe the beginning of the process of boulder-clay-making. As we follow the fragments of the same disrupted rock which occur in the till farther down the valley, we note how they become smaller in size; while the sharp corners at the same time get rubbed away, and the surfaces assume the characteristic glacial markings. The stones and boulders in the till thus vary much in size—from mere grit and small fragments no larger than a hazel-nut up to great blocks measuring many feet and even yards across. These last, however, are the exception, and are generally met with at no distance from their parent stratum. Large, far-travelled boulders in the till are always well abraded, and invariably consist of some hard, durable rock. Considerable lumps of soft sandstone and friable shale, on the other hand, have never been able to stand a long journey under the ice. They rapidly broke up into small pieces, and were ground and rubbed down into sand and clay. The enormous pressure exerted by the ice is well shown in these and other phenomena—more especially in the appearance which the till not infrequently presents of having been forcibly intruded into the strata over which it was dragged and rolled by the superincumbent ice. Veins and tongues appear squeezed between the interstices of the rocks, and sometimes sheets of till seem as if actually interstratified with the old strata. Perhaps the most striking example of this peculiar phenomenon which has been recorded is that shown in the quarry of Linksfield, near Elgin, which has been described by Captain Brickenden.[1] This quarry has been opened in limestone underneath an overlying thickness of forty feet of Oolitic strata, which were separated from the limestone by a sheet of boulder-clay two to four feet thick. In order to raise the limestone it was found necessary to remove the boulder-clay and strata resting upon it, which, since the opening of the quarry up to the time when Captain Brickenden examined the place (1851), had been done to the extent of 120 yards in a direction at right angles to the course pursued in the excavation of the limestone, the transverse line or section of the quarry extending to 270 yards. Now, over all this area the boulder-clay maintained its position between the Oolitic strata above and the limestone below; and Captain Brickenden was "assured by an intelligent old man, who had visited the quarry very constantly since it was first opened, that at the distance of more than 100 yards from where it now is the clay was observed to be about the same depth, and overlaid, as now, by the same series of Oolitic strata in their undisturbed position. On the north-western boundary of the quarry the thickness of the intercalation increases considerably, and there can be little doubt that in this direction the clay obtained an entrance." The surface of the boulder-clay and that of the strata between which it occurs is hardened, abraded, polished, and marked with striæ, indicating the direction in which the ice-movement took place, which is nearly from north-west to south-east. Captain Brickenden was of opinion that the boulder-clay had been intruded into its present position. It is more probable, however, that the whole mass of the Oolitic strata has been pushed out of place, and dragged forward bodily over a pavement of boulder-clay under the enormous *mer de glace* which pressed outwards by way of the Moray Firth and overflowed all the low grounds of Elgin.

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[1] *Quart. Journ. Geol. Soc.*, vol. vii. p. 289.

The "carry" of the stones in till is another indication of the direction of ice-flow; and the evidence thus supplied confirms that afforded by all the phenomena of glaciation touched upon in the preceding paragraphs. The stones are scattered about promiscuously in the clay, but they nevertheless show a method in the mode of their occurrence, the meaning of which is obvious. We do not in the till of one place meet with an assemblage of blocks and boulders which may have come from any and every part of the country. On the contrary, the contents of the accumulation bear a strict relation to the geology of the neighbourhood in which that deposit occurs. Thus, in a district composed of Carboniferous strata, most of the stones in the boulder-clay consist of fragments of sandstone, limestone, black shale, coal, and other rocks pertaining to the surrounding neighbourhood. And not only so, but the clay itself acquires a dark dingy gray or blue colour, just such a hue as those various members of the Carboniferous formation would assume were they all pounded up and mixed in a mortar. Hence, as we traverse the country we become aware that the colour, the texture, and the stony contents of the till vary as we pass over different geological formations. If, for example, we set ourselves down, say at the head of the Tweed, in the heart of the Silurian Uplands, we find the till of that district crammed with fragments of Silurian rocks alone, and we note that the colour is generally a pale brown. Till of this character continues far down the valley, until, by and by, after we have passed certain of the lateral streams that enter the Tweed from the north, we encounter occasional boulders of sandstone and porphyrite which have come down the valleys of the Lyne and the Eddlestone waters. But Silurian fragments continue to form the great bulk of the stones all the way down to where, a little beyond Galashiels, we enter upon the Old Red Sandstone area. Very soon after passing the boundary-line between the two formations, we notice that boulders of red sandstone make their appearance, at first sparingly, and then in rapidly increasing numbers. The clay at the same time gradually loses its grayish brown tint, and acquires a redder hue, which by and by deepens into a red as pronounced as that of the Old Red Sandstone itself. Owing, however, to the superior hardness of the Silurian fragments, which could resist crushing and grinding much more effectually than the softer sandstones, the boulders derived from the regions above Galashiels are always present in large numbers. As we continue on our way down the valley we pass numerous knolls, hills, and wider sheets of various igneous rocks, and no sooner do we pass one of these than fragments of it appear in the till. Search the whole wide valley from its source to its termination, and we shall not find a single example of a boulder-clay stone which has travelled *up* the valley, or in any other direction than that followed by the trend of the striæ and the drums. And the same holds true of every region in Scotland.

There are many other facts connected with the stones in the till, and which all point to the same conclusion, namely, that the till is the bottom-moraine of the old ice-sheet; but these I need not discuss in this place. I may merely refer in a word to the occurrence here and there, in and underneath the till, of patches and irregular layers and beds of coarse shingle, large boulders, earthy angular or sub-angular gravel, waterworn stones, sand, and laminated clay—all these point to the fact that during the accumulation of the till water circulated to some extent underneath the ice. The deposits in question mark the sites of sub-glacial channels and lakelets which formed from time to time, and were doubtless often shifted by movements in the ice overhead. This is shown by the manner in which the beds are usually abruptly cut asunder, contorted, confused, bent back upon themselves, and even frequently coiled up and involved with the till in such a way as to prove that they have been rolled forward with the boulder-clay *en masse*.

In remarking upon the fact that the direction of movement of the Scottish ice-sheet was determined by the form of the ground, I referred to a great deflection of ice-flow caused by the meeting of the *mers de glace* of the Highlands and Southern Uplands. A much more striking example of this kind of deflection remains to be mentioned. In Caithness the boulder-clay has yielded many broken sea-shells, not a few of which are finely striated. Perfect shells are rarely met with. The broken fragments are scattered about in precisely the same manner as the stones, and they belong to a heterogeneous mixture of arctic, boreal, and southern forms.[1] For a long time the origin of this shelly clay was a puzzle, but the solution of the puzzle was at last furnished by my colleague Dr. Croll,[2] who pointed out that the clay was the bottom-moraine of a *mer de glace* which had overflowed Caithness from south-east to north-west, to do which it must first have traversed the Moray Firth, and hence came the shelly *débris* and certain stones that, so far as we know, could have been derived from no other direction. This bold suggestion met with considerable opposition when it was first made, for it involved a most remarkable conclusion. Dr. Croll showed that the ice which overflowed Caithness had been deflected out of its normal path by the presence of another immense *mer de glace* flowing outwards from Scandinavia, and he further maintained that the Islands of Orkney and Shetland, when they came to be thoroughly examined, would prove to be striated from east to west. This conclusion has been subsequently borne out by the observations of my brother, Professor Geikie, and Mr. B. N. Peach, in Caithness,[3] and by a detailed examination of the Shetlands[4] by the latter in company with Mr. J. Horne, and similar results have been obtained by the same geologists in Orkney. Not only are the Shetlands striated across in a general east and west direction, but the till covering the western part of the islands is crammed with stones derived from the east. My friend, Mr. Amund Helland, of Christiania, has also visited these islands, and confirmed the observations made by my colleagues.[5] The striæ and the carry of the stones in the till along the whole eastern seaboard south from Aberdeenshire tell the same tale. They indicate the presence in the area of the North Sea of some obstacle to the outflow of the ice from Scotland, which, instead of going right out to sea, was deflected and compelled to hug the Scottish shores in a south-easterly direction.[1]

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[1] See *Quart. Journ. Geol. Soc.* (Jamieson), 1866, p. 261.

[2] *Geol. Mag.*, vol. vii. p. 209.

[3] *Great Ice Age*, p. 179.

[4] *Quart. Journ. Geol. Soc.*, v. xxxv. p. 778.

[5] *Zeitschr. deutsch. geol. Ges.*, Bd. xxxi. (1879), p. 63.

Thus are we driven to conclude that during the climax of the Glacial Period all Scotland was drowned in a wide-spread *mer de glace,* which coalesced in the north and east with a similar sheet of ice that crept outwards from Scandinavia. To the west the Scottish ice, meeting with no impediment to its course, overflowed the Outer Hebrides to a height of 1600 feet, and probably continued on its path into the Atlantic as far as the edge of the 100-fathom plateau, where the somewhat sudden deepening of the sea would allow it to break off, and send adrift whole argosies of icebergs. The height reached by the upper surface of the ice that overwhelmed the Outer Hebrides enables us to ascertain the angle of slope between those islands and the mainland. This was 1 in 211, that is to say, the inclination of the surface of the ice-sheet was about 25 feet in the mile—an inclination which would appear to the eye almost like a dead level.[2]

I have been thus particular in my sketch of the salient features of the general glaciation of Scotland during the culmination of the Ice Age, because in describing them I am practically describing the similar glacial phenomena of Ireland, and a large part of England, of Scandinavia, Finland, Denmark, and Northern Germany. It will, therefore, not be necessary to do more than give a brief sketch of the limits reached by the great *mer de glace* in Northern Europe, so far as these have been definitely ascertained by an appeal to such facts as those I have mentioned in connection with the glacial phenomena of Scotland.

Glacial striæ and boulder-clay have been followed over all

Great Ice Age, p. 180.

[2] J. Geikie, *Quart. Journ. Geol. Soc.,* v. xxix. p. 861.

Ireland, and the admirable researches of a long list of Irish geologists, including Griffiths, Oldham, Portlock, Jukes, Hull, Du Noyer, Kinahan, Close, Hardman, Campbell, and many others, have conclusively established the fact that our sister island was buried under an ice-sheet hardly less extensive than that which overwhelmed Scotland. Two sketch-maps, showing the general trend of the striæ in Ireland, have been published—the first by Rev. Maxwell Close, than whom no one has contributed more to our knowledge of Irish glacial geology,[1] and the second, which being the more recent, contains the largest amount of information, by Professor Hull.[2] From these maps we gather that the ice flowed off Ireland in all directions save to north-east in Antrim, upon the coast of which it encountered the Scottish *mer de glace,* which forced it to turn away to north-west and south-east; but along the whole western and southern shores, where no obstacle to its passage intervened, it seems to have swept in one broad and continuous stream out, probably as far as that of Scotland, into the Atlantic. The thickness attained by the ice that flowed into the Irish Sea from Scotland, where it coalesced with the *mer de glace* coming from the eastern sea-board of Ireland, and also, as we shall presently see, with that creeping out from England and Wales, makes it quite certain that the area now occupied by that sea must at that time have been filled with glacier-ice.

The phenomena of glaciation are well developed throughout extensive areas in England and Wales. Those of the Northern Lake District and Lancashire and Cheshire have been studied in great detail, and the movements of the ice, as determined by the direction of *roches moutonnées* and striæ, by the distribution of the till, and by the carry of the stones in that deposit, have been well ascertained by many enthusiastic workers, following in the wake of Agassiz[3] and Buckland,[4] among whom are

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[1] *Geol. Mag.*, vol. iv. p. 234.

[2] *Physical Geology and Geography of Ireland*, p. 211. The general reader who desires a well-digested summary of what is known of the old ice-movements in Ireland, would do well to consult this interesting treatise.

[3] *Proc. Geol. Soc.*, vol. iii. p. 328.

[4] *Ibid.*, pp. 332, 345.

Binney,[1] Bryce,[2] Hull,[3] Morton,[4] Mackintosh,[5] De Rance,[6] Tiddeman,[7] Ward,[8] Goodchild,[9] and others. Mr. Tiddeman gave the first connected account of the phenomena as developed in North Lancashire and adjacent parts of Yorkshire and Westmoreland, and established the fact that the *mer de glace* which covered those regions was compelled to flow against the "grain" of the country, crossing wide and deep valleys in a S.S.E. direction. This he showed was due to the fact that the great ice-stream flowing outwards from the Lake District barred the passage of the Lancashire ice in the direction of the basin of the Irish Sea. In short, as already stated, the Scottish, Irish, and English *mers de glace* coalesced. The course of this united ice-sheet is further indicated by the glacial phenomena of the Isle of Man, long ago studied by Rev. J. Cumming,[10] and by those of Anglesey, as described by Professor Ramsay.[11] This latter island is striated from N.N.E., and its boulder-clay contains stones which have come all the way from Cumberland.

Turning our attention now to the north-eastern borders of England, we find that the rock-striæ, and the carry of the stones in the till of the maritime districts of Northumberland and Durham, tell the same tale as those of North Lancashire—the ice to which they owe their origin, instead of flowing straight out to sea, kept on a S.E. course. In fact it flowed in a direction as near as may be parallel to the trend of the present coast-line. It will be remembered that along the eastern sea-board of Scotland the ice was deflected from its path and compelled to flow in the same direction. Despite the pressure exerted by the massive sheet that made its way outwards from the Pennine Chain, the English ice could not escape into the basin of the North Sea, and consequently we find stones from Scotland, Northumberland, and Durham plentifully present in boulder-clay all along the eastern maritime districts of England. More than this, when we get as far south as the Humber, and follow the spoor of the ice as indicated by the carry of the boulder-clay stones, we are led across Lincolnshire into the Midland Counties, by Nottinghamshire and Leicestershire. The rocks in these districts are too soft as a rule to have preserved any striæ, but the general trend of the stones is in the direction I have indicated. The North Sea was filled with a massive *mer de glace* continually advancing in a general S.S.W. direction—the presence of which is distinctly traceable in the remarkable deflection of the glaciation all along the sea-board of Scotland, from Stonehaven southwards. It was simply owing to the superior elevation and extent of the Scottish mountains that the narrow strip of low-lying ground in the eastern maritime districts of that country was not invaded by an alien ice-stream. When we pass into England the hills become lower, and the area of low ground between the hills and the sea increases in breadth. There was thus less and less opposition offered to the southward advance of the North Sea *mer de glace* as it pressed upon the eastern shores of England, until eventually it overflowed bodily and crept south-west across the Midland tableland on its way to the valley of the Severn and the Bristol Channel. This remarkable glacial invasion is proved not only by the carry of local stones, and stones which have come south from the northern counties and Scotland, but by the appearance in the till at Cornelian Bay and Holderness of boulders of two well-known Norwegian rocks, which were recognised by Mr. Amund Helland.[1] And Mr. Plant mentions the occurrence in boulder-clay farther inland, at Leicester, of certain "hornblendic-looking masses, neither dolerite nor diorite, but fibrous or slaty rather than granular,"[2] which are possibly also of Norwegian origin. Doubtless, when the geologists of the Midland Counties have exhausted the investigation of the older glacial deposits of these districts, we may expect to hear of many similar "finds."

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[1] *Mem. Lit. and Phil. Soc. Manchester*, 2d Ser. vol. viii. p. 195.

[2] *Brit. Assoc. Rep.* 1850, pp. 76, 112; 1855, p. 80.

[3] *Edin. New Phil. Journ.*, 2d Ser. vol. ix. p. 31; *Mem. Lit. and Phil. Manchester*, 3d Ser. vol. i. p. 131; *Mem. Geol. Surv. Gt. Britain*, 1864.

[4] *Proc. Geol. Soc. Liverpool*, vols. xiv. (1860) p. 35; viii. (1867) p. 4; *Brit. Assoc. Rep.* 1870, p. 81.

[5] *Geol. Mag.*, vols. ii. p. 299; vii. pp. 349, 445, 564; viii. pp. 250, 303; ix. p. 399; *Quart. Journ. Geol. Soc.*, vols. xxv. p. 407; xxviii. p. 388; xxix. p. 351; xxx. p. 174; xxxi. p. 692.

[6] *Geol. Mag.*, vols. vi. p. 489; viii. pp. 107, 412; *Quart. Journ. Geol. Soc.*, vol. xxvi. p. 641.

[7] *Quart. Journ. Geol. Soc.*, vol. xxviii. p. 471.

[8] *Ibid.*, vols. xxix. p. 422; xxx. p. 96; xxxi. p. 152; "Geology of the Lake District," *Mem. Geol. Surv. England and Wales.*

[9] *Geol. Mag.*, Dec. ii. vol. i. p. 496; *Quart. Journ. Geol. Soc.*, vol. xxxi. p. 55.

[10] *Guide to the Isle of Man*, p. 249.

[11] *Quart. Journ. Geol. Soc.*, vol. xxxii. p. 116.

The ice which would thus appear to have streamed transversely across England eventually coalesced with that which overflowed from the basin of the Irish Sea south-east through Cheshire, together with that which streamed east from the Welsh Uplands, and the united *mer de glace* thereafter made its way into the Bristol Channel. Here it joined the thick ice that flowed out to sea from the high grounds of South Wales—the bottom-moraine of which is conspicuous not only in the mountain-valleys of that region, but also upon the low-lying tracts that extend from the hills to the sea. In the south-eastern counties, so far as we know at present, the ice-sheet at the climax of the Glacial Period did not extend farther than the valley of the Thames, beyond which no trace of its bottom-moraine has been met with.[3]

The pressure exerted by the ice-sheet as it crept over England is well shown by the size of the great erratics of chalk, which are here and there enclosed in the boulder-clay of East Anglia. These have evidently been displaced and carried forward along with the sub-glacial *débris* with which they are associated. Some of the blocks referred to are so large that they have been quarried. Many occur in Norfolk, where they have long been known, but one of the most noted by reason of its great size is that which is exposed in the clay-pit, called Roslyn Hole, near Ely. This erratic is composed of a mass of Chalk, Gault, and Upper Greensand, and measures over 480 yards in length by 44 yards in width. The Rev. O. Fisher was the first to recognise its true character,[1] Mr. Seeley having previously accounted for its presence by a fault or dislocation.[2] But Professor Bonney has shown that Mr. Fisher's interpretation of the phenomena is correct[3]—a conclusion which is likewise supported by the testimony of Mr. Skertchly, who states that he has seen boulder-clay underlying all the various rocks of which this enormous erratic is composed.[4] Similar large detached masses of marlstone are described by Mr. Judd as appearing in the boulder-clay of Lincolnshire,[5] and Professor Morris mentions the occurrence in the drift of the same county of a large erratic of Oolitic rock measuring 430 feet long by 30 feet thick at its deepest part, which he saw exposed in the railway cutting at the south end of the tunnel (Great Northern Railway).[6]

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[1] *Zeitschr. deutsch. geol. Ges.*, 1879, p. 67; *Archiv for Mathematik og Naturvidenskab.*, 1879, p. 287. See further on this subject Appendix B.

[2] *Brit. Assoc. Rep.*, 1874, p. 197.

[3] For fuller details I may be allowed to refer to *Great Ice Age*, chaps. xxviii.-xxx. where references will be found to various authorities for the facts upon which the above conclusions are based. Mr. S. V. Wood's papers on the glacial geology of East Anglia will be found particularly instructive, and I say this not the less readily, because I find myself compelled to dissent from some of his theoretical views.

The lower part of the boulder-clay in Cretaceous districts is frequently crammed with masses of chalk and chalk-*débris*, and these are so often crushed and kneaded together that it is difficult sometimes to distinguish between the broken upper surface of the undisturbed chalk and the highly chalky till that overlies it. And not only so, but occasionally we find the till and the chalk appearing to alternate in successive irregular layers, some instructive examples of which were pointed out to me by Mr. Skertchly in the neighbourhood of Brandon and Thetford in Sussex.

Nowhere in Europe are the old glacial phenomena developed on so imposing a scale as in Scandinavia. If we except the higher mountain-tops, the whole of the great peninsula has been wrapped in ice, the erosive effects of which are seen in the severely glaciated aspect of the exposed rock-surfaces, and the massive sheets of boulder-clay which cover so large a portion of the low grounds of Sweden. The investigations of many geologists in Norway—of Keilhau,[1] Durocher,[2] Martins,[3] Scheerer,[4] Hörbye,[5] Kjerulf,[6] Sexe,[7] Reusch,[8] Helland,[9] S. A. Sexe,[10] Pettersen,[11] and others, have familiarised us with the fact that the deep fiords of Norway were filled to overflowing during the Ice Age with vast glaciers. And the remarkable fact that the high grounds, which form the boundary-line between Norway and Sweden, were traversed in the region lying south-east of Trondhjemsfjord by ice flowing across the watershed towards the north-west, was indicated more than twenty years ago by Hörbye. This and many other facts have led to the conclusion that the whole Scandinavian peninsula was formerly enveloped in a great *mer de glace*, and the direction followed by the ice has been traced in sufficient detail to enable us to form a definite view of the principal movements. In the mountainous regions of Norway the ice flowed invariably in the direction of the main fiords and principal valleys—the irregularities of the ground giving rise, as in Scotland, to numerous local deflections. In Sweden the prevalent trend of the striæ corresponds likewise with the average inclination of the ground, but as large tracts bordering on the Baltic have only a small elevation, the ice was enabled to traverse those regions in a direction that has frequently no reference to the present lines of drainage. Thanks to the labours of the older school of Swedish geologists, amongst whom Sefström[1] stood conspicuous, and to the later works of Holmström, A. Erdmann, Torell, Törnebohm, E. Erdmann, Nathorst, Hummel, Gumælius, Lindström, Holst, and others,[2] we know that the ice flowing from Scandinavia was sufficiently thick to fill up the basin of the Baltic Sea, and to override all the islands—Åland, Gottland, Öland, Bornholm, etc. The investigations of geologists in Finland and Northern Russia[3] have further proved that the Scandinavian *mer de glace* advanced in force, and flowed south-east across Finland. Forchhammer long ago described the striated rocks of Faxö (Denmark),[4] and Johnstrup's[5] observations lead us to conclude that the great Scandinavian ice-sheet crossed from Sweden, and spread its bottom-moraine over Denmark.

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[1] *Geol. Mag.*, vol. v. p. 407. [2] *Ibid.* vol. ii. p. 529. [3] *Ibid.* vol. ix. p. 403.

[4] *Geology of the Fenland* (*Mem. Geol. Surv. Engl. and Wales*), p. 236.

[5] *Explanatory Memoir of Geol. Survey's Map* (*England*), Sheet 64.

[6] *Quart. Journ. Geol. Soc.*, vol. ix. p. 320.

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[1] *Nyt Mag. for Naturvid.*, Bd. i. 1838 ; *Ibid.*, iii. 1841 ; *Ibid.*, iv. 1845.

[2] *Bull. Soc. Géol. France*, 2e Sér. t. iii. p. 65 ; t. iv. p. 29 ; *Comptes Rendus de l'Acad. des Sci.*, t. xxi. p. 1158 ; t. xxii. p. 116 ; t. xxiii. p. 206 ; *Voyages de la Commission Scientifique du Nord en Scandinavie, Laponie, etc.*

[3] *Bull. Soc. Géol. France*, 2e Sér. t. iii. p. 102 ; t. iv. p. 891 ; *Edin. New Phil. Journ.*, vol. xliii. p. 109.

[4] *Annalen der Physik und Chemie* (*Poggendorf*), Bd. lxvi. (1845) p. 269 ; *Nyt Mag. for Naturvid.*, Bd. vi.

[5] *Universitets-Program* (Christiania), 1857.

[6] *Ibid.* 1860 and 1870 ; *Udsigt over det sydlige Norges Geologi*, 1879.

[7] *Universitets-Program*, 1864 and 1866.

[8] *Vidensk. Selsk. Forhandl.* (Christiania), 1868.

[9] *Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar*, 1875, p. 53 ; *Om de isfyldte Fjorde og de glaciale Dannelser i Nordgrönland ; Quart. Journ. Geol. Soc.*, 1877, p. 142 ; *Archiv for Mathematik og Naturvidenskab*, 1878, p. 387.

[10] *Universitets-Program* (Christiania), for 1874 ; *Archiv for Mathem. og Naturvid.*, 1877, p. 469.

[11] *Arch. for Mathem. og Naturvid.*, 1877, pp. 272, 318.

How far south the *mer de glace* extended into Germany no one until very recently has attempted to prove. So far back as

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[1] *Konigla Svenska Vetenskaps-Akademiens Handlingar*, 1836, p. 141.

[2] Holmström, "Jagttagelser öfver Istiden i södra Sverige," 1866, *Lunds Univ. Årsskrift.*, t. iii. For an excellent résumé of Swedish glacial phenomena see Professor A. Erdmann's *Exposé des Formations Quaternaires de la Suède*, 1868. Papers of later date are numerous, see especially Torell, "Undersökningar öfver Istiden," *Öfversigt af K. Vet.-Akad.*, 1872 and later years; also papers by Törnebohm, Erdmann, Nathorst, Holst, and others, in *Geologiska Föreningens i Stockholm Förhandlingar*, Bd. i.-iv.; and various memoirs by members of the Swedish Geological Survey (Sveriges Geologiska Undersökning),—Gumælius, *Öfver. af K. Vet.-Akad. Förh.*, 1871; Nathorst, *Ibid.*, 1873; Hummel, *Bihang till K. Svenska Vet.-Akad. Handlingar*, 1874; Gumælius, *Ibid.*, 1874 and 1876.

[3] Böhtlingk, *Edin. New Phil. Journ.* (1841), vol. xxxi. p. 103; Nils de Nordenskiöld, *Beitrag zur Kenntniss der Schrammen in Finland*, 1863; Graf Keyserling, *Bull. de l'Acad. des Sci. de St. Pétersbourg*, t. v. p. 505; Schmidt, *Ibid.*, t. viii. p. 348; Helmersen, *Mem. de l'Acad. Imp. des Sci. de St. Pétersbourg*, 7 Sér., t. xiv., No. 7; *Comptes Rendus de l'Acad. des Sci.*, t. lxx. p. 51; Jernström, "Om Qvartärbildningarna," *Bidrag till Kannedom af Finlands Natur och Folk*, No. 20.

[4] *Oversigt over det Kgl. Danske Vidensk.-Selsk. Forh.*, 1843, p. 103.

[5] *Beretningen om Mödet af* 11*te Skandinaviske Naturforskermöde i Kjöbenhavn*, 1873, p. 69; *Zeitschr. deutsch. geol. Ges.*, 1874, p. 533.

1832, however, Professor A. Bernhardi speculated on the probability that the polar ice had formerly invaded Germany, and spread as far south as the most southerly limits reached by the glacial deposits, which he recognised as nothing less than the morainic detritus left behind it by the ancient *mer de glace*.[1] But this sagacious observer was nearly half-a-century before his time, and it is no wonder that his work should have remained buried in oblivion until it was recently unearthed by Professor G. Berendt. Agassiz likewise has speculated about the possibility of a *mer de glace* having overflowed Germany. He was of opinion, indeed, that the British Islands, Sweden, Norway and Russia, Germany and France, the mountainous regions of the Tyrol and Switzerland down to Italy, formed but one ice-field, the southern limits of which remained yet to be determined. My friend Dr. Croll in a sketch-map showing the path of the ice-sheet in the area of the North Sea has also indicated the Scandinavian ice as overflowing Germany farther south than Berlin.[2] Indeed the probability that the glacial detritus, so enormously developed in Northern Germany, is the product of land-ice rather than the random droppings of icebergs has often been suggested in conversation by glacialists in this country, and I gave expression to these surmises in the first edition of my *Great Ice Age*.[3] But detailed proofs could not then be adduced in support of that view. Geologists had completely forgotten Bernhardi's investigations, and those of Sefström and Naumann had likewise been overlooked. I believe it was generally understood, at least by British geologists, that no glacial striæ had up till a year or two ago been detected anywhere in the low grounds of Northern Germany. Yet Sefström, as early as 1836, mentions that Professor Rose had informed him of the occurrence of a striated rock-surface in a limestone-quarry at Rüdersdorf to the east of Berlin. The markings had been exposed upon the removal of some thickness of undisturbed superficial soil, and seem greatly to have astonished the intelligent overseer of the quarry. Unfortunately, before Rose arrived upon the scene the rock had been blasted and broken up, and so he missed the opportunity of being the first geologist to examine and describe glacial striæ in Germany. This good fortune was reserved for Naumann, who some eight years later detected them near Wurzen in Saxony.[1] This discovery, however, was soon forgotten, and German geologists continued to hold to the opinion that all the drift-phenomena of the low grounds were due to the action of icebergs and marine currents, until in 1875 Professor Otto Torell, recalling the observations of Sefström and Rose, boldly formulated the view that the whole of Northern Germany had been overflowed by the Scandinavian *mer de glace.*[2]

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[1] *Leonhard and Bronn—Jahrbuch*, 1832, p. 257.

[2] *Climate and Time*, p. 449.

[3] See pp. 390, 505.

This theory met with much opposition, but it has had the desired effect of awakening amongst German geologists a livelier interest in the study of the glacial phenomena of their country. Those who know how thickly North Germany is clothed with drift-deposits, and how seldom the rock-surface is exposed, need feel no surprise that the true character of the boulder-clay of that region should have remained so long undetected, or that in such a country many geologists should still hesitate to admit the sufficiency of Torell's theory. Early in 1879 Professor G. Berendt in an able paper[3] attempted to combine the glacier- and iceberg-theories, much in the same manner as geologists here have tried to do. He admits the existence of a great *mer de glace* covering Scandinavia and the high grounds of Finland at the same time that Northern Germany was submerged. With him the boulder-clay of the northern regions, which were covered by glacier-ice, is a true ground-moraine; while the boulder-clay and other drift deposits of Germany represent the droppings of icebergs, and the work of marine currents. Very shortly afterwards, however, appeared a remarkable paper by Professor H. Credner,[4] in which he described the occurrence of rounded and striated rocks in the vicinity of Leipzig. A few miles east and north of that town several bosses, knolls, and rounded ridges of quartz-porphyry project for some 30 or 40 feet above the general level of the surrounding flat country, which is everywhere clothed with boulder-clay and gravel. All these prominent knolls have evidently been subjected to glacial action, and show the characteristic rounded and smoothed surfaces. Not only so, but in some places, as upon the hill called Kleine Steinberg, there are polished faces exhibiting well-marked parallel striæ and grooves, which point from N.N.W. to S.S.E. The boulder-clay of the neighbourhood contains many stones which could only have come from the north, and amongst them are fragments of certain characteristic Scandinavian rocks. Dr. Penck has also detected another similar knoll of porphyry (Dewitzer Berg) near Taucha, eight miles distant from that just referred to, which likewise shows a mammillated, polished, and striated surface—the scratches agreeing in direction with those upon the glaciated rocks nearer Leipzig. MM. Torell and Helland, who visited this locality in company with Professor Credner, agreed with him that the *roches moutonnées*, the polishing and striation, were undoubtedly the work of land-ice, and they had no difficulty in deciding from the position of the *Stossseite* that the glaciating agent had flowed into Saxony from the north-west. As to the character of the boulder-clay there could be just as little doubt. It was as usual an unstratified mass, crammed with angular and sub-angular stones, not a few of which could be certainly recognised as of Scandinavian origin. Credner, Torell, Helland, and Penck, were all agreed as to its having formed the bottom-moraine of a *mer de glace*. More recently glacial striæ have been noticed on the Galgenberge near Halle (on the Salle), and on the Rainsdorfer Berge, and the Pfarrberg, near Landsberg.[1]

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[1] *Neues Jahrbuch*, etc., 1844, pp. 557, 561, 680.

[2] *Zeitschr. deutsch. geol. Ges.*, 1875, p. 961.

[3] *Ibid.*, 1879, p. 1.

[4] *Ibid.*, 1879, p. 21.

It is impossible to enter into details here, but I may refer very briefly to certain other facts which serve to confirm the view that the great boulder-clay deposits of Northern Germany are true ground-moraines.[1] In many places the rock upon which the boulder-clay reposes, instead of being smooth and polished, shows a smashed and jumbled surface—precisely similar to that which I have mentioned in connection with the glacial phenomena of Scotland. The boulder-clay is, in fact, mixed up with the shattered rock, and in some places appears even to have been intruded between the strata, so as to assume the aspect of an intercalated bed. By far the most remarkable example of these striking phenomena which has yet been described is that of Möens Klint (Denmark). The wonderful exposure of chalk and boulder-clay which appears upon the north-east coast of the island of Möen has long excited the surprise of geologists. The phenomena have been described by Puggaard, and a résumé of the chief features of interest is given in Lyell's *Antiquity of Man.* The island is composed of white chalk, for the most part horizontally bedded, and covered by a series of glacial deposits lying in a similar undisturbed position. But along the north-east coast, where the cliffs reach to a height of 400 feet, the most extraordinary contortions and displacements of the strata are exhibited. The chalk is fissured, dislocated, and displaced—twisted, bent, and convoluted from top to bottom, and the boulder-clay partakes of the same disturbance. At one place, according to Lyell, the folds of the strata are "so sharp that there is an appearance of four distinct alternations of the Glacial and Cretaceous formations in vertical or highly-inclined beds; the chalk at one point bending over, so that the position of all the beds is reversed."[2] Here and there irregular-shaped masses of boulder-clay are actually surrounded on all sides by chalk, and so striking indeed is the behaviour of the boulder-clay that Forchhammer may well be pardoned for having speculated upon its eruptive origin. Puggaard was of opinion that all this confusion was due to movements of the earth's crust—to convulsions and "faults" caused by the action of the subterranean forces, and in this view he was followed by Lyell. But Johnstrup has since reinvestigated the evidence and come to quite a different conclusion. He shows, in his interesting papers already referred to, that the disturbances can only be attributed to the enormous pressure and disrupting force of the Scandinavian *mer de glace,* which filled up the basin of the Baltic and overflowed Denmark. Chalk is just one of those rocks which would be most readily ruptured and displaced under the crushing weight of the advancing ice-sheet, and many good examples of this striking phenomenon have been recorded. Chalk boulders of large size are met with in many districts in Denmark, Holstein, and Germany. Thus Bruhns describes a chalk erratic in the boulder-clay of East Holstein (Pariner Berg), which measured 86 feet in length, 10 feet in breadth, and 12½ feet in thickness.[1] But even harder and less easily ruptured strata than chalk occasionally show a highly-broken surface below till. Thus, the limestone (Muschelkalk) at Rüdersdorf, near Berlin, is smoothed and striated in some places, while in other places it is much broken up, and the shattered *débris* and displaced blocks are incorporated in the bottom-part of the boulder-clay.[2] Similar appearances are met with in the till that overlies the hard Silurian greywacké of Saxony, as we shall see presently. But the phenomena certainly occur on the largest scale with such strata as chalk and the various Tertiary formations, which yielded more readily to the pushing and crushing of the ice-sheet. Thus, at Teutschenthal, near Halle, in Saxony, the boulder-clay is described by Helland[3] as appearing often like veins and patches in the Brown Coal formation, underneath the main mass of the boulder-clay—the Tertiary strata are frequently bent and broken, the coal-beds being sometimes caught up and included *en masse* in the till. Here and there, also, large detached fragments of the Tertiary beds appear scattered through the boulder-clay in the same manner as other erratics, and some of these are veined with boulder-clay. More than this, wide stretches of the coal-bearing strata appear intercalated in the glacial deposits as if they formed part and parcel of one and the same series, in which position they have actually been mined. Similar phenomena characterise the glacial deposits of Mecklenburg-Schwerin, as described by Professor F. E. Geinitz. He tells us that so large are some of the erratics of chalk which occur in the boulder-clay (*Blockmergel*), that they were at one time mistaken for protruding hillocks of the rock in place. Further examination of this province has proved that the Cretaceous strata are often much broken, disturbed, and displaced—the boulder clay appearing as if interstratified with the chalk in such a manner that a boring-rod passed down through the Cretaceous rocks would go through alternating beds of chalk and glacial deposits. Many borings in the chalk of the Diedrichshagener Bergen have proved that the Cretaceous strata there are underlaid by boulder-clay, and are thus themselves only a gigantic boulder. They have been pushed out of place, and dragged forward by the ice.[1] Professor H. Credner, in a most instructive paper, has recently described many similar appearances in connection with the boulder-clay of Saxony. He shows that frequently the Silurian rocks are broken and ruptured, and the resulting *débris* enclosed in the lower part of the boulder-clay. The sections he gives as illustrations of this are sufficiently remarkable, but the most striking examples of disruption, contortion, and displacement are supplied, he says, by the Brown Coal formation (Oligocene). Boulder-clay and glacial gravel are confusedly commingled with the brown-coal beds, the latter being often crumpled up and contorted, and so squeezed that long tongues are seen protruding into the boulder-clay. The same phenomena, he shows, are characteristic of the gravel-beds associated with the till—they

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[1] O. Luedecke: *Neues Jahrbuch für Min. Geol. und Pal.*, 1879, p. 567.

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[1] Two admirable papers (the one by A. Helland, and the other by A. Penck) on the glacial phenomena of Northern Germany, etc., appear in the same volume of the German Geological Society's Journal as that last cited (1879, pp. 63, 117). In these will be found an exhaustive account of all that is known upon this subject, with many interesting proofs of the former existence of the great *mer de glace.*

[2] *Antiquity of Man*, p. 391, 4th Edit.

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[1] *Zeitschr. deutsch. geol. Ges.*, Bd. i. p. 111.

[2] Penck. *Op. cit.*

[3] *Zeitschr. deutsch. geol. Ges.*, 1879, p. 72.

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[1] *Beitrag zur Geologie Mecklenburgs* (Neubrandenburg, 1880), pp. 20, 39. For another interesting example, see Boll's description of the bed of chalk near Malchin, in Mecklenburg. This layer is some 35 feet in thickness, and rests upon a dark-coloured boulder-clay, which has been pierced in borings to a depth of 43 feet. *Geognosie der deutschen Ostseeländer*, 1846, p. 136.

are twisted, abruptly truncated, displaced, and fantastically jumbled, in such a way as to suggest that the deposits have been dragged forward under great pressure. In the sections given by him to illustrate the aspect assumed by the disturbed Oligocene strata, it may be observed that the contorted coal-beds are bent over in one determinate direction, thus indicating the path followed by the disturbing agent.[1]

These and other appearances bear testimony to the enormous pressure exerted by the ice-sheet, and are totally inexplicable on the iceberg-hypothesis. We have, in short, every reason for concluding that the northern *mer de glace* advanced as far south as the most southerly limits reached by the great "Northern Drift."

Upon the map of Europe (Plate D) which accompanies this volume, I have indicated the area covered by the ice-cap—the southern boundary-line corresponding very nearly with that which Murchison and his colleagues have given,[2] as the extreme limits reached by the "erratic formation." The fine lines are meant to show the principal directions in which the upper strata of the ice flowed. These, as a rule, correspond to the average trend of rock-striations, *roches moutonnées*, and the carry of the stones in the till. In other words, the whole body of the ice pressed forward in certain general directions. Nevertheless, there is abundant evidence to show that the under strata of the ice, influenced by the configuration of the ground, frequently moved in directions quite at variance with what must have been the flow of the upper strata. The long bent red arrows upon the map indicate the trend of the lower strata in one or two places. Upon a larger map more might have been inserted, but those given will sufficiently illustrate

[1] *Zeitschr. deutsch. geol Ges.*, 1880, p. 75. Credner's paper contains numerous references to the literature of this interesting subject, and gives by far the most complete account of the phenomena which has yet appeared. The facts brought forward by him appear to me sufficient of themselves to demonstrate the subglacial origin of the till, and to show that Saxony was formerly overflowed by the great *mer de glace*.

[2] *Geology of Russia and the Ural.*

the phenomena in question. Let me briefly state the grounds for believing that the under strata of the *mer de glace* flowed round the south coast of Norway. At various points upon that coast, as near Dybvaag, at Bliksund between Lillesand and Christiansand, and even as far north as the district of Jæderen, occur several erratics of zircon-syenite, and other rocks which could only have been derived from Skien, Laurvig, and Fredriksværn in Langesundfjord near the opening into Christiania-fjord.[1] These are the rocks which have already been referred to as having been obtained by Mr. Helland in the boulder-clay of Holderness. Now the Admiralty's charts show that a deep hollow extends all round the south coast of Norway—the limits of which are indicated upon my map by the two dotted lines. In Bohus Bay, we find depths ranging from 700 up to nearly 2000 feet. Opposite Arendal the depth is even as much as 2580 feet. The trough seems to become shallower off the coast of Jæderen, where, however, it is still more than 1000 feet deep. In the Skaggerak, just outside of the trough, the sea does not average more than 150 feet in depth, so that in Bohus Bay the hollow is some 2400 feet deeper. Even as far west as Jæderen the bed of the great hollow is still 700 or 800 feet below the average level of the sea-bottom immediately to the south and south-west. Now it is evident that the lower strata of the great *mer de glace* could not ignore this profound hollow, but would naturally tend to follow it in its course to west and north-west; and thus boulders and morainic material derived from the Christiania district would tend to travel in a direction at right angles to that followed by the upper strata of the ice which flowed (as the striæ in the fiords and on the high grounds of Southern Norway attest) towards the south. Notwithstanding that westerly determination of the under strata, however, the influence of the upper strata could not but be propagated to a great depth in the *mer de glace*, and thus the ice below would gradually tend to be dragged up the southern slopes of the trough, until eventually it made its escape and flowed on with the general *mer de glace* of the North Sea. I have indicated the probable path of the bottom ice by the diverging arrows. A portion would spread away to north-west, while another part seems to have swept on with the ice that flowed south-west towards the English coast. It is by this circuitous route that I believe the Norwegian boulders in the till of Cornelian Bay and Holderness have come.[1] While such was the course followed by a portion of the bottom-ice that flowed from the Christiania district, there can be little doubt that this was only a local deflection due to the configuration of the ground, and that the main mass of the ice, from base to surface, flowed S.S.W. from Christiania-fjord, and crossed Denmark into Germany, for we find erratics of the same origin as those above referred to, in Jutland, in the island of Laaland, in the island of Urk in the Zuider Zee, and at Hamburg.

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[1] Kjerulf: *Udsigt over det sydlige Norges Geologi*, p. 31.

To support an ice-sheet extending over twenty degrees of latitude, and showing a width of little less than 3000 miles, great humidity and extreme cold were required. It is quite impossible that the vast sheet of ice which overwhelmed all Northern Europe could have been fed by the snows that fell upon the mountains of Scandinavia and the British Islands. The precipitation must have been excessive over the whole area, and the cold which enabled the snow to accumulate and become perennial upon the low grounds of England and Northern Germany could not have been other than severe in the extreme. Some geologists have supposed that the great *mer de glace* poured down upon Europe from the polar regions. But this is disproved by the direction of the striæ in the north of Norway, in the Shetland Islands, and the Outer Hebrides. The *mer de glace* must have terminated in a steep ice-wall facing the Atlantic. It did not, all events, reach the Færöe Islands, for, as Mr. Helland and I found during a recent visit, these islands supported a local and independent ice-sheet of their own, which flowed outwards in all directions into the surrounding ocean.

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[1] For further remarks upon the deflections of the European *mer de glace*, see Appendix, Note B. I need hardly remind the geological reader that in this chapter I refer only to the ice-sheet at the period of its greatest extension. Of the smaller ice-sheet of the latest glacial epoch I speak in a subsequent chapter.

CHAPTER XI.

THE GLACIAL PERIOD—*Continued.*

Ancient glaciers of north and south sides of the Alps, of the Jura Mountains, of the Black Forest, of the Vosges, of the Carpathians, of the Ural, of the Pyrenees and the Cantabrian Mountains, of Central and Southern Spain, of Corsica, of the Apuan Alps, of the Caucasus, of the Lebanon, of the Atlas Mountains—Erratics in the Azores—Limestone-breccias of Gibraltar—Breccias, etc., of Malta—Loam with flints of Northern France—"Head" of maritime districts of the Channel area—Stanniferous gravels of Cornwall—Glacial phenomena of North America—Angular earthy *débris* of North Carolina—Volume of water discharged from ancient glaciers—Quantity of mud in water coming from glaciers—Origin of löss and loamy deposits of Rhine, Danube, etc., of Central Europe—Origin of the Tchernozem or "black-earth" of Southern Russia—Objections to Baron Richthofen's löss-theory—Summary of conditions during Glacial Period.

It has long been a familiar fact that the glaciers of Switzerland formerly assumed gigantic proportions, and the first to recognise this was Venetz,[1] a Swiss engineer, whose observations date back so far as 1821, thus making him the father, as it were, of glacial geology. He was followed by a long line of illustrious men—Charpentier,[2] Agassiz,[3] Desor,[4] Guyot,[5] Ch. Martins,[6] Escher von der Linth,[1] and others—who succeeded in demonstrating that the low grounds of Switzerland during the Glacial Period were totally overwhelmed by great glaciers descending from every mountain-valley. The old glacier of the Rhone we now know covered all the area presently occupied by the Lake of Geneva, and reached to a height of very nearly 4000 feet upon the slopes of the Jura.[2] In some places, indeed, it even overflowed through passes in those mountains at a height of over 3000 feet, a long stream of ice advancing north-west through the French Jura by way of Pontarlier, and reaching to beyond Ornans in the valley of the Loue, a tributary of the river Saône.[3] The main trunk of the Rhone glacier, as we learn chiefly from the researches of MM. Falsan and Chantre,[4] made its way out of Switzerland and flowed far south into the plains of France, its spoor having been traced down to Lyons and Vienne in the valley of the Rhone. In like manner all the valleys that open north from the Alps and the Tyrol were filled with great glaciers, which spread themselves far out upon the low grounds of Baden, Hohenzollern, Würtemberg, Upper Swabia, and over wide areas in Upper Bavaria and Upper Austria.[5]

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[1] *Bibliothèque Universelle de Genève*, t. xxi.; *Denkschr. der Schw. Ges. für die gesamt. Naturwissensch.*, Bd. i., 1833. See also an interesting posthumous paper, "Mémoire sur l'extension des anciens glaciers," etc., *Nouveaux Mémoires de la Soc. Helv. des Sci. Nat.*, 1861, vol. xxiii.

[2] *Essai sur les Glaciers et sur le Terrain Erratique du Rhône*, 1831.

[3] *Études sur les Glaciers*, chap. xvii.

[4] *Comptes Rendus de l'Acad. des Sci.*, t. xiv. (1842), p. 412; *Bull. Soc. Géol. France*, 1846, t. iii. p. 528; *Ibid.*, 1851, t. viii. p. 64.

[5] *Bull. Soc. des Sciences Nat. de Neuchâtel*, 1847, t. i. pp. 477, 507.

[6] *Edin. New Phil. Journ.*, 1847, vol. xliii. p. 54.

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[1] *Ueber die Gegend von Zürich in der letzten Periode der Vorwelt*, 1852.

[2] Professor Renevier has recently traced the frontal moraine of this ancient glacier, which is perfectly continuous, along the flanks of the Jura for a distance of six miles between Mauborget and Ste. Croix. It reaches a breadth that varies between 500 and 1500 mètres, and attains a culminating point of 1233 mètres.—*Bull. Soc. Vaud. Sciences Nat.*, t. xvi. (81) p. 21.

[3] Benoit: *Bull. Soc. Géol. France*, 3e Sér. t. v. p. 61.

[4] *Ibid.*, 2e Sér. t. xxvi. p. 360; *Mem. de l'Acad. des Sciences, Belles-Lettres, et Arts de Lyon*, 1869; *Bibliothèque Universelle de Genève*, 1870; *Compt. Rend. Assoc. Franç. pour l'Avanc. des Sciences*, 1873; *Monographie géologique des anciens glaciers et du terrain erratique de la partie moyenne du bassin du Rhône* (1879).

[5] For descriptions of glacial phenomena on north and east side of Alps—Baden, Würtemberg, Swabia, Upper Bavaria, Tyrol, and Austrian territories—see Gerwig: *Verh. der naturw. Vereins, Carlsruhe*, Bd. v. p. 89; Simony: *Jahrb. der k.-k. geol. Reichsanst.*, Bd. ii. p. 153; *Verh. der k.-k. geol. Reichsanst.*, 1869, p. 296; *Mitth. des österreich. Alpenv.*, Bd. i. (1863) p. 178; *Denkschr. der k. Akad. der Wissensch. Wien*, 1871, p. 501; Probst: *Jahresh. des Vereins für vaterl. Naturk. Württemberg*, 1866, p. 45; *Ibid.*, 1874; Steudel: *Ibid.*, 1866, p. 104, and 1869, p. 40; *Archives des Sciences Phys. et Nat.*, 1867, t. xxix. p. 209; Gredler: *Programm der k.-k. Gymnasiums in Botzen*, 1867-68; Trinker: *Jahrb. der k.-k. geol. Reichsanst.*, 1851, Bd. ii. p. 74; Götsch: *Zeitschr. des*

Enormous ice-streams at the same time occupied all the main valleys on the southern side of the Alps, and, descending to the plains of Piedmont, Lombardy, and Venetia, piled up huge moraines of gravel, sand, blocks, and *debris*, some of which would in this country pass for considerable hills. The beautiful lakes of Northern Italy during the climax of the Ice Age had no existence, their basins being occupied by massive glaciers. From the Stura in the Maritime Alps of Sardinia, east as far as the Mur in Styria, we find abundant traces in almost every valley of the former presence of great glaciers.[1] The ice-streams which descended from the northern slopes of the Alps appear in some cases to have become confluent upon the low grounds, so as to form a more or less continuous *mer de glace*, sloping outwards from the base of the mountains, and the same was the case with some of those which flowed towards the south, especially in Lombardy.[2]

The smaller mountain-groups of Central Europe had also at the same time their perennial snow-fields and glaciers. Numerous moraines of local glaciers occur in the Jura, as was first indicated many years ago by MM. Pidancy and Lory,[3] and

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deutsch. und österreich. Alpenv., Bd. i. p. 583 ; Stark : *Ibid.*, 1873, p. 67 ; Pichler : *Neues Jahrbuch für Mineralogie*, etc., 1872, p. 193 ; Gümbel : *Sitzungsb. der math.-phys. Klasse der königl.-bayerisch. Akad. der Wissensch. München*, 1872, p. 224 ; Zittel : *Ibid.*, 1874, p. 252 ; Hilber : *Jahrb. der k.-k. geolog. Reichsanst.*, Bd. xxix. p. 537. A good general description and sketch-map of the ancient glaciers of Switzerland is given by Dr. F. Kinkelin, *Bericht über die Senckenberg. naturforsch. Ges.*, 1874-75, p. 77 ; see also Heer's *Urwelt der Schweiz*, and Favre's *Recherches Géologiques*, etc.

[1] Dr. Pilar mentions that even in the Agram hills traces of glacial action are met with : *Verhandl. der k.-k. geolog. Reichsanst.*, 1876, p. 233.

[2] For descriptions of ancient glaciers of south side of Alps, see Martins and Gastaldi : *Bull. Soc. Géol. France*, 2^{e} Sér. t. vii. p. 554 ; Omboni : *Atti della Soc. Ital. di Scienze Nat. in Milano*, vol. ii. p. 6, with map of the ancient glacier-system of Lombardy ; see also *Op. cit.*, vol. iii. p. 337 ; Mortillet : *Ibid.*, vol. iii. (1861) p. 44, with a general map of the ancient Italian glaciers ; Stopanni : *Geologia d'Italia*, Pte. 2^{a}. The ancient glacier of the Drave is described by Hofer : *Neues Jahrbuch für Mineralogie*, etc., 1873, p. 128 ; see also Dr. Taramelli's paper : *Atti Soc. Ital. Sci. Nat. Milano*, vol. xiii. (1870) p. 224. A general map showing the extent of glacial deposits on both sides of the Alps accompanies Rütimeyer's paper : *Ueber Pliocen und Eisperiode auf beiden Seiten der Alpen*, 1876.

[3] Ch. Martins : *Annales de la Soc. d'Émulation des Vosges*, t. vi. (1847). A more detailed description of the glaciers of the Jura is given by Dr. Benoit : *Actes*

there are similar accumulations met with in some of the valleys in the Black Forest.[1] The moraines and the morainic gravels of the Vosges have been rendered familiar to geologists through the writings of Hogard, Collomb, Benoit, and Grad,[2] from whom we learn that those mountains were formerly covered with perennial snow-fields that nourished many important ice-flows, although, like the Black Forest and the Jura, their valleys now contain no glaciers, nor is there any tradition of their former existence. According to M. Grad, however, temporary glaciers now and again form in the upper cirques of the valleys in the Vosges between 1200 and 1300 mètres of elevation.[3] Well-marked moraines are met with in the Carpathian mountains, showing that they also formerly supported ice-streams. Thus Professor Zeuschner[4] has noted the occurrence of moraines in the valley of Biaty Dunajee in the Tatra, and similar phenomena have been observed in the same part of the range by the Austrian Geological Survey.[5] They have been recorded also from the Czerna Hora in the East Carparthians by MM. Paul and Tietze,[6] and from the Theiss Valley by Messrs. R. L. Jack and J. Horne, who show that this valley has been filled with a glacier upwards of 45 miles in length.[7] Again, we learn from M. Poliakoff that the Ural Mountains, which were supposed to bear no trace of glacial action, do nevertheless show unmistakable rock-striations, moraines with scratched stones, and erratics.

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de la Soc. Helvétique des Sciences Nat. (Porrentruy) 1853, p. 231 ; *Bull. Soc. Géol. France*, 2e Sér. t. xx. p. 321.

[1] C. Vogt and Dolfuss-Ausset : *Course dans la Forêt-Noire en* 1846 ; Ramsay : *Quart. Journ. Geol. Soc.*, 1862, p. 186 ; Gillieron : *Archives des Sciences Phys. et Nat.*, 1876, p. 32 ; Platz : *Neues Jahrbuch für Mineralogie*, etc., 1878, p. 56.

[2] Hogard : *Annales de la Soc. d'Émulation d'Épinal*, 1840, p. 91 ; 1842, p. 524 : *Bull. Soc. Géol. France*, t. ii. p. 249. *Coup d'Œil sur le Terrain Erratique des Vosges*, 1851 ; Collomb : *Preuves de l'Existence d'Anciens Glaciers dans les Vosges*, 1847 ; Benoit : *Bull. Soc. Géol. France*, 2e Sér. t. xv. p. 638 ; *Bull. Soc. Hist. Nat. de Colmar*, 1862 ; Grad : *Bull. Soc. Géol. France*, 3e Sér. t. i. p. 514.

[3] *Comptes Rendus de l'Acad. des Sci.*, t. lxxiii. (1871), p. 390.

[4] *Sitzungsb. der math.-naturw. Klasse der k. Akad. der Wissen.*, Bd. xxi. (1856), p. 259.

[5] F. von Hauer : *Geologie der österr.-ungar. Monarchie*, p. 122.

[6] *Verh. der k.-k. geol. Reichsanstalt*, 1876, p. 296 ; *Ibid.*, 1877, p. 85 ; *Ibid.* 1878, p. 142.

[7] *Quart. Journ. Geol. Soc.*, vol. xxxiii. p. 673.

He observed these in crossing the range by Ekaterinburg on his way to the Obi. Just before reaching Ekaterinburg many *trainées* of immense boulders running in parallel directions were conspicuous, while farther east, on the shores of the Obi (near to the mouth of the Irtysch), the superficial sands contained in their lower portions many well-polished and striated boulders.[1]

Still more remarkable, however, are the evidences of glacial action in Western and South-western Europe. MM. Collenot and J. Martin have shown that in the Morvan, near the sources of the Seine, there is an abundant development of rock-striations, striated stones, and erratics, which indicate the former presence of very considerable *nappes* of ice.[2] Similar appearances show themselves in the plateau of Central France. Not only have many of the valleys of that region been filled with glaciers, but extensive sheets of ice have overflowed the low grounds at the base of the hills—scouring, striating, and polishing the rocks, and covering them with a thick deposit of *moraine profonde.* Large glaciers have descended from Mont Dore and the Puy de Dome, and from the heights of Cantal, and their terminal and lateral moraines are now conspicuous at the base of the mountains and in such valleys as those of Allagnon, the Couze d'Issoire, the Couze de Champeix, the Dordogne, etc. Traces of the same nature occur in the neighbourhood of Clermont Ferrand, which bespeak the former existence of several glaciers of the second order, as in the valleys of the Auzon and of Romagnat. In short, it is evident that the great plateau of crystalline rocks upon which are superposed the volcanic cones and masses of Auvergne, has been covered with a *mer de glace* from which glaciers protruded on all sides into the valleys. From the crests of Forez and Mezeuc, and from the basaltic plateaus of Aubrac and Vivarais, glaciers of more or less importance have descended.[3]

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[1] *Nature,* 1877, p. 306.

[2] Collenot : *Bull. Soc. Géol. France,* 2^e Sér. t. xxvi. p. 173 ; Jules Martin ; *Ibid.*, 2^e Sér. t. xxvii. p. 225.

[3] For old glaciers of Central France, see Ch. Martins : *Comptes Rendus de l'Acad. des Sci.* t. lxvii. p. 993 ; *Quart. Journ. Geol. Soc.*, vol. xxv. p. 46 ; Lecoq :

Even the hills of La Madelaine, which drain into the Loire, are thought to have supported perennial snow and ice.[1]

But none of the old glaciers of Central France could vie with the great ice-flows of the Pyrenees, several of which attained colossal proportions, and deployed upon the low grounds at the base of the mountains. According to MM. Martins and Collomb, the ancient glacier of the valley of Argelès flowed from a height of about 3000 mètres for a distance of 53 kilomètres, and deposited its moraines upon the low grounds within 15 kilomètres of Tarbes, at an altitude of only 400 mètres. The ice was not less than 850 mètres thick in a part of its course. The ancient glaciers of the valleys of La Pique and the Garonne, as described by M. Piette, were equally extensive, and their history, like that of the Argelès glacier, is read in striated surfaces, *roches moutonnées,* perched blocks, lateral and frontal moraines, and widespread sheets of till or boulder-clay—the *moraine profonde* of the glaciers. On the Spanish side of the Pyrenees the glaciers did not apparently attain so great a development. I may add that the Cantabrian mountains, which are a continuation of the Pyrenees, exhibit in the valleys that open to the north many traces of considerable glaciers.[2]

The mountains of Central and Southern Spain also contain relics of the Ice Age, glacial deposits having been noticed in the Sierra Guadarrama to the north of Madrid,[3] and by MM. Schimper and Collomb in the Sierra Nevada, where large

Les Périodes Geologiques de l'Auvergne, 1867 ; Delanoüe : *Bull. Soc. Géol. France,* t. xxv. p. 402 ; Julien : *Phénomènes Glaciaires dans le Plateau Central,* 1869 ; Marcou : *Bull. Soc. Géol. France,* 1870, p. 361 ; *Das Ausland,* 1872, pp. 460, 512 ; Fabre : *Comptes Rendus de l'Acad. des Sci.,* t. lxxvii. p. 495 ; Hooker : *Nature,* vol. xiii. p. 31 ; Symonds : *Ibid.,* vol. xiv. p. 179.

[1] Tardy : *Bull. Soc. Géol. France,* 2^{e} Sér. t. i. p. 514.

[2] For descriptions and notices of glacial phenomena of the Pyrenees see—Charpentier : *Essai sur les Glaciers,* 1841 ; *Bibliothèque Universelle de Genève,* t. lv. (1845), p. 126 ; De Collegno : *Ann. des Sci. Nat.,* t. ii. p. 191 ; Garrigou : *Bull. Soc. Géol. France,* 2^{e} Sér. t. xxiv. p. 577 ; Martins and Collomb : *Ibid.,* 2^{e} Sér. t. xxv. p. 141 ; *Brit. Ass. Rep.* 1866, p. 52 ; Piette : *Bull. Soc. Géol. France,* 3^{e} Sér. t. ii. p. 498 ; *Comptes Rendus de l'Acad. des Sci.,* t. lxxxiii. p. 1187.

[3] Don Casiano de Prado : *Descripcion fisica i geologica de la Provincia de Madrid,* p. 164.

erratics are so numerous and conspicuous that they long ago attracted the attention of travellers. Perhaps as striking as these glacial phenomena are those described by M. Desor as occurring in the Maritime Alps and the neighbourhood of Nice.[1] And equally remarkable are the relics of the Ice Age in the island of Corsica, which were first noticed by Collomb nearly thirty years ago.[2] In the valley of the Tavignano he observed the *moraine profonde* of an extinct glacier, which, as the nature of the stones in the moraine showed, had descended from the slopes of Monte Rotonda (2763 mètres). The moraine was deeply trenched and denuded, and occurred at a height of 430 mètres. Six years later Mr. Pumpelly discovered polished rock-surfaces and *roches moutonnées,* together with large erratics and terminal moraines, in the valleys coming down from the mountain of Baglia Orba (2650 mètres). The lateral moraines rose to a height above the bottoms of the valleys of 100 feet, and the frontal moraines were some 40 or 50 feet high.[3] Again, M. Tabariés de Grandsaignes detected moraines and huge erratics in the region of Monte Cinto, which testified to the former presence of two glaciers.[4]

Seeing that Corsica has thus supported its snow-fields and glaciers, we might have expected that the Apennines could hardly fail to exhibit similar traces. A number of years ago (1866) Professor Cocchi stated his belief that glaciers had formerly existed in the Apuan Alps,[5] and their moraines have been more recently described by Stopanni as being well developed in the Val d'Arni.[1] Professor Moro has likewise given an admirable account of the ancient glacier that formerly occupied the valley of the Serchio and covered a large part of Tuscany.[2] Even in the Apennines proper it would seem that glaciers have formerly existed, Sig. Ferrero having noted the occurrence in the vicinity of Monte Majella of moraines, glacial lakes, and huge erratics.[3] That similar relics of the Ice Age will yet be discovered in other mountainous regions of our continent which have not been particularly examined may be confidently expected.

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[1] *Compt. Rend. de l'Acad. des Sci.*, t. lxxxviii. (1879) p. 760; see also "Sur les Terrains Glaciaires Diluviens et Pliocènes des Environs de Nice:" *Bull. Soc. Niçoise des Sci. Nat. et Hist.*, 1879.

[2] *Bull. Soc. Géol. France,* 2e Sér. t. xi. p. 66.

[3] *Ibid.*, 2e Sér. t. xvii. p. 78.

[4] *Ibid.*, 2e Sér. t. xxvi. p. 270. Waltershausen notes the occurrence on the west coast of Elba of fragments of a peculiar kind of gabbro, which does not belong to that island. Were these brought thither by tidal action from Corsica, or could they possibly have been transported by floating-ice?—See *Nat. Verh. Holl. Maat. Weten. Haarlem,* Dl. xxiii.

[5] *Atti Soc. Ital. Sci. Nat.*, t. ii. (1866); *Boll. R. Com. Geol. d'Italia* (1872), t. iii. p. 187.

The Terek-thal and other valleys of the Caucasus, as we learn from M. Abich,[4] were formerly occupied by very considerable glaciers; and, according to Palgrave, the mountains in the provinces of Trebizond and Erzeroum likewise nourished glaciers of no mean size.[5] Coming farther south we find similar traces of former ice-action in the Lebanon—the famous cedars, as Dr. Hooker tells us,[6] growing upon old moraines; and on reading the accounts given by travellers in other parts of Asiatic Turkey, one cannot help surmising that in the mountain-regions of those countries glacial phenomena are probably more abundantly developed than is at present supposed.[7]

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[1] *Rendiconti del Reale Istituto Lombardo*, t. v. p. 733; *Atti Soc. Ital. Sci. Nat.*, t. xv. p. 133; *Geologia d'Italia*, pte. 2^a, p. 127.

[2] *Il gran Ghiaccio della Toscana*, 1872; see also Stefani, *Boll. R. Com. Geol. d'Italia*, 1874, p. 86; *Ibid.*, 1875, p. 1.

[3] *Antico Ghiacciajo della Majella*, 1862.

[4] *Mem. de l'Acad. des Sci. de St. Pétersb.*, 6 Sér. t. vii. p. 515; *Études sur les Glaciers actuels et anciennes du Caucasus*, Tiflis, 1870; *Bull. de l'Acad. Imp. des Sciences de St. Pétersb.*, 1871, p. 245. See also Freshfield's *Travels in the Central Caucasus and Bashan.*

[5] *Nature*, vols. v. p. 444; vi. p. 536.

[6] *Nat. Hist. Review*, Jan. 1862.

[7] The Rev. E. J. Davies, in *Life in Asiatic Turkey*, makes frequent reference to the occurrence of dome-shaped smoothed rock-surfaces, observed by him in the mountainous district of Marash. In one place (p. 111) he says: "After an hour's riding over rocky slopes of this kind (described as 'sheets of smooth limestone lying at a considerable inclination'), we entered a district of stiff yellow clay, tenacious as pitch, and filled with great angular pieces of black lava, which rang like metal under the horses' feet. Into this pudding-like mass of tenacious clay, mud, and stones, the horses plunged up to the knees, at times up to the belly." Can this be a boulder-clay of glacial origin?

In the Great Atlas terminal moraines 800 or 900 feet in vertical height were observed by Sir Joseph Hooker, and Messrs. Ball and Maw,[1] at an elevation of 6000 feet. They describe also the occurrence of a remarkable series of ridges and rolling hummocks and masses of angular *débris*, 300 or 400 feet in height, and some 3000 feet above the sea-level, which extend along the base of the great escarpment that rises abruptly from the wide plains or table-lands of Marocco. The mounds do not rest directly against the escarpment, but occur as "isolated mounds 200 or 300 feet in advance, sloping down towards the escarpment in one direction, and in the other rolling away in great wave-like ridges and undulating sheets, which terminate at a well-marked line of demarcation, just where the level portion of the plain commences." Where the internal structure of those mounds was visible, the angular blocks of which they consisted showed a disposition in layers sloping away from the escarpment toward the plain. The stones had evidently been derived from the lofty escarpment (1000 feet), and Mr. Maw thought the mounds were "the result of glaciers covering the escarpment, leaving on their recession the intermediate depression." More recently M. Ch. Grad noticed what he took to be moraines at the mouth of the gorge of El Kantara, on the southern side of the Atlas in Algeria. These he describes as accumulations of erratic *débris*, but he saw no polished rocks and no striated stones.[2] I may note here in passing that Mr. Hartung observed in the Azores a number of erratics of granite, which have evidently been carried there by floating-ice. Even at the present day icebergs go as far south as the latitude of those islands, but they keep to the mid-ocean between the Azores and the American coast. When northern erratics were transported to the Azores it is most probable that the Arctic Current extended farther to east than it now does.[3]

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[1] *Journal of a Tour in Marocco and the Great Atlas.* See also *Quart. Journ. Geol. Soc.*, vol. xxviii. p. 85.

[2] *Bull. Soc. Géol. France*, 3^e Sér. t. i. p. 87.

[3] *Origin of Species*, 6th ed. p. 328.

But glacial moraines and rock-striæ are not the only physical evidence of a former general refrigeration of climate in Europe. There are certain superficial phenomena which, although they cannot be referred to the action of glaciers, are yet sufficiently suggestive of colder conditions than the present. Of such a nature are those massive "breccias" or agglomerations of angular *débris*, and those more or less loose heaps and sheets of earthy rubbish and rock-fragments, which occur in such bulk and in such positions, as to show that they could not have been formed under present conditions. A very good example of this is furnished by the massive limestone-breccias of Gibraltar, which have been described by Professor Ramsay and myself.[1] The famous Rock is composed almost entirely of limestone-strata, which generally dip at a high angle. It rises, as is well known, in the form of a narrow sharp ridge, that shoots nearly south into the Mediterranean. Inland it terminates in an almost perpendicular wall that rises to a height of 1349 feet. To the east it presents "a bold escarpment, which is for the most part inaccessible, and in places almost vertical, the cliffs where they are lowest having a drop of not less than 300 or 400 feet, and of more than 1000 feet where they approach the sea on the north. From their base the ground falls rapidly away to the coast-line, at angles that vary from 30° to 40°." The slopes facing Gibraltar Bay are not so steep, as will be seen from the accompanying section (Fig. 6), which gives the profile on a true horizontal and vertical scale. The dominating point of the Rock is 1396 feet.

It will be observed that the limestone-strata (*L*) dip steeply to the west, where they are succeeded by beds of shale and thin bands of grit and limestone at *S*. The "faults" or dislocations I need not consider, as they are of older date than the phenomena we are about to discuss. Resting upon the surface of the shale (*S*) will be observed a deposit marked *B*. This consists of a heterogeneous accumulation of angular fragments and blocks of limestone, embedded in a matrix of calcareous grit and earth, the whole forming a rock-mass as solid as the limestone of Gibraltar itself. It varies in thickness from a few feet up to 30 or 40 yards, and it may be thicker than that where it enters the sea, for the base of shale and limestone on which it rests is not there visible. It covers wide areas of the low grounds, especially in the district of Buena Vista and Rosia, and in the neighbourhood of the South Barracks, attaining its greatest thickness towards the sea, and thinning off as it approaches the steeper slopes of the Rock. All round the Rock similar masses of breccia occur. There can be no possible doubt that these breccias have been derived from the Rock itself; they consist exclusively of angular fragments of limestone, not a single stone foreign to the place being visible. It is also equally certain that what-

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[1] *Quart. Journ. Geol. Soc.*, 1878, p. 505.

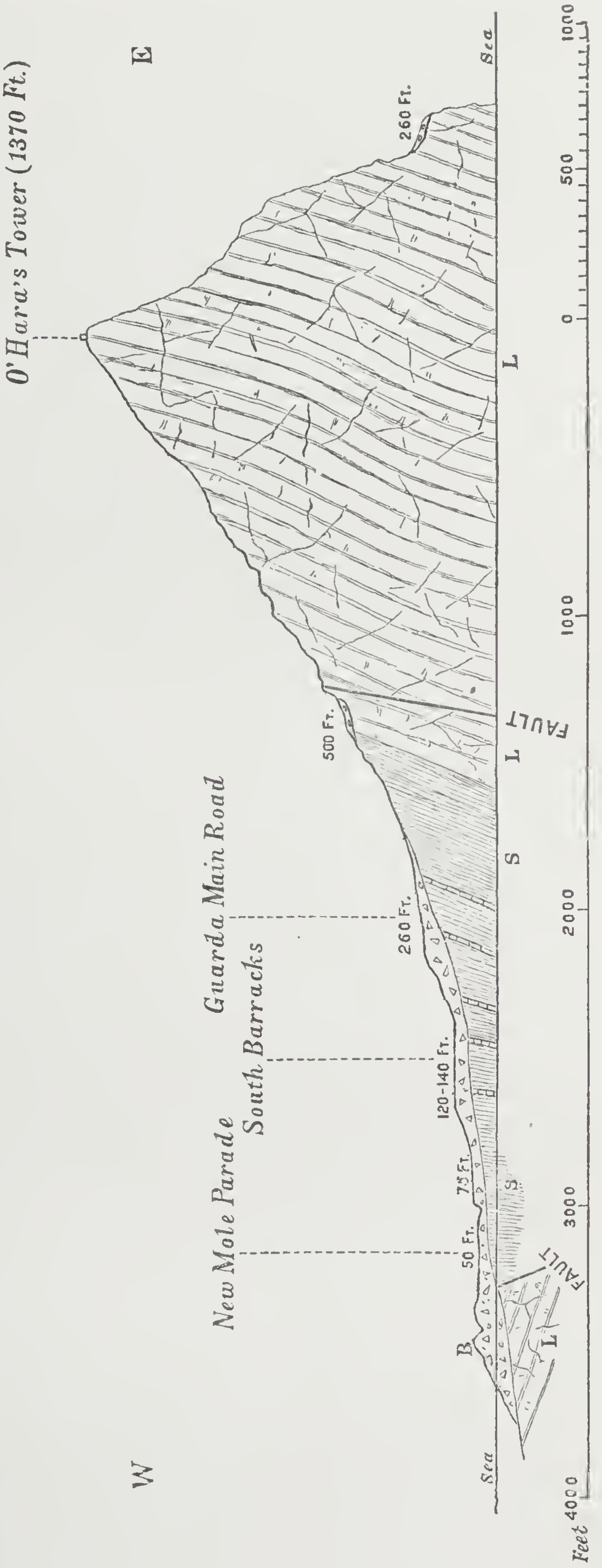
E
O'Hara's Tower (1370 Ft.)
Sea
260 Ft.
L
500 Ft.
FAULT
L
S
Guarda Main Road
South Barracks
New Mole Parade
260 Ft.
120-140 Ft.
75 Ft.
50 Ft.
S
FAULT
B
L
W
Sea
1000
500
0
1000
2000
3000
4000
Feet

Fig. 6.—Section across Rock of Gibraltar.

ever their origin may be, they are not now accumulating. On the contrary, since the time of their formation they have experienced very considerable "denudation;" they have been furrowed and worn and trenched by rain and torrents, in precisely the same manner as the limestone from which they have been derived. And not only so; but the sea during some period of submergence has carved out horizontal terraces in them which are continuous with similar ledges excavated in the highly-inclined calcareous strata. The breccias are obviously of subaerial origin, but they indicate the former existence of conditions very different from the present, for they can only be the result of severe frosts. It is evident that such were needed to wedge out the larger blocks that occur in the breccia, some of which measure several yards in diameter, and must weigh 20 or 30 tons at least. Moreover, the sharply-angular shape of the stones is further proof that these have not been subjected to the action of torrents or the sea. There was a time, then, in the geological history of Gibraltar when the winters were so severe that the limestone-beds were ruptured and shattered, and the slopes of the Rock became covered over with sheets of loose, angular *débris* and large blocks. But some force other than frost was needed to carry this *débris* down the gentler slopes, and to spread it over the low grounds that extend outwards to the sea. Hard frosts might no doubt disintegrate the limestone, and scatter the fragments over the steeper slopes; but the impetus with which these rolled downwards would not suffice to carry them across the low grounds, a distance of 550 yards at least, over which the average inclination of the ground is not more than 8° or 9°, while in some places the slope does not exceed 2° or 3°. What appears to be the true explanation of the phenomena may be observed in most alpine regions, where hard frost and heavy snowfalls occur. If we suppose that in former times thick snow mantled the slopes of the Rock, we shall have all the conditions necessary for the origin of rock-*débris*, and its translation over the low grounds to what is now the sea-bottom. The limestone would break up all along the sharp ridge, and the loose *debris*, falling upon the snow, would be slowly carried downward by the movement of the *névé*. Vast quantities of *débris* would thus tend to collect at the base of the Rock, and when the snow melted in summer, the rubbish, becoming saturated, would tend to move forward *en masse*, like the so-called "earth-glaciers" of the Rocky Mountains.[1] Thus in time all the low grounds would become more or less completely buried.

Similar irregular masses and sheets of calcareous breccia and loose angular *débris* occur at low levels in other parts of the Mediterranean region, as in Corsica, Malta, and Cyprus, which are not now accumulating, but evidently belong to some past period, when the subaerial forces acted with more intensity than at present. Some of these have been attributed to devastating torrents, others to violent inroads of the sea, just in the same manner as it was formerly attempted to account for the erratic phenomena of alpine regions and Northern Europe. They deserve, however, to be reconsidered with the light which recent advances in our knowledge of the Glacial Period have thrown upon such questions. In the extremely interesting account of the Maltese breccias given by Professor Leith Adams,[2] we read of accumulations of great blocks, mixed with angular *débris* and fine loam, which it is difficult to believe can be due to the action of occasional deluges such as he attributes them to. When one remembers the limited drainage-area of the island and the small height of the watershed, it is hard to understand how torrents sufficiently powerful to sweep along blocks "fully fifteen feet in circumference" could have originated in Malta, unless under very different conditions of climate. It is quite possible, however, that when Malta formed part of the Continent, it may have experienced winters as severe as those which cloaked the slopes of Gibraltar with heavy snow.

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[1] Hayden: *Geological and Geographical Survey of Colorado*, 1873, p. 46. The phenomena observed by Mr. Maw and his fellow-travellers at the base of the great escarpment of the Atlas, bear a strong resemblance to those of the Gibraltar breccias. May not they have a similar origin?

[2] *Notes of a Naturalist in the Nile Valley and Malta*, 1870.

At present the winter temperature (January) of Gibraltar is 54°·7 F., while that of Malta is 54°·5 F., so that it is not unreasonable to suppose that during the Glacial Period heavy snow in winter may have covered the more elevated parts of Malta, and hard frost may have ruptured the rocks in the same manner as at Gibraltar. Much angular *débris* and masses of broken limestone and sandstone would thus tend to gather and be swept down into hollows and over the faces of cliffs, so as to form long, sloping taluses.

In the same way I would account for much of that loose earthy rubbish with angular blocks which one may observe in the lower valleys of the Apennines and the Apuan Alps, and indeed in nearly every part of Europe. The quantities of more or less loose angular *débris* which one encounters almost universally in districts where no such *débris* is now accumulating or travelling forward, speak to conditions of transport which now obtain only in more elevated and northern regions. "Such drifts deserve," as the Rev. W. S. Symonds has remarked,[1] "*especial attention;*" and I quite agree with him that "they appear to owe their origin to a period when there was greater transportation of angular and sub-angular *débris* by rain-wash and melting snow, or *névé,* than there is at present." It is highly probable, for example, that much (I do not say all) of that coarse loamy clay with angular flints which M. de Mercey has described as being so widely spread in Picardy may be due to the action of frost and the movement of heavy sheets of *névé,* which in some places, perhaps, may have passed into ice, and exerted considerable erosive action upon the rocks over which it crept. Of the Pleistocene age of this particular deposit there can be no doubt. But in other areas of Northern France we find similar wide-spread sheets of clay and sand which have been assigned by French geologists sometimes to the Pleistocene, and sometimes to Tertiary periods. Among the most remarkable examples of such superficial accumulations are those which overlie the Cretaceous strata of the Paris Basin. They have been frequently described, and their origin has been a much disputed question. M. de Cossigny has recently renewed the interest of French geologists in the subject, and presented them with a very clear description of the phenomena as displayed in the southern part of the Paris Basin, from which we learn that there are two separate layers of superficial *débris*—the lower one an unstratified clay with flints, and the upper a deposit of sand also containing flints. The lower bed, which rests immediately upon the chalk, consists of a confused mass of flints, the interstices between which are filled with a white or yellow clay, which, on account of its refractory properties, is much used for the making of the ovens or kilns in which porcelain is baked. All the flints come from the chalk—not only from the Lower Cretaceous strata which are now all that remain of the formation in the region described by M. de Cossigny, but also from different stages of the upper division, as is proved by the fossils which the flints contain. "These flints," he says, "are quite unaltered; they have preserved their natural colour, their texture, their white porous surface; they are only, for the most part, more or less broken, but the fractures are always fresh, the angles perfectly sharp, and when they are washed and divested of the clay that adheres to their surface, a mineralogist could not distinguish between them and the flints recently extracted from one of the chalk-quarries of Normandy. This state of perfect preservation is due without doubt to the impermeable nature of the clay in which they are imbedded, which has protected them from atmospheric influences. But what is most worthy of notice is the fact that they show no trace of wearing, and have evidently never been rolled about by water." Those of a spheroidal form are frequently entire, while those of irregular shape have nearly always been divested of their projecting knobs and tubercles. Again, of those which are about the size of one's fist, and which have not preserved their original shape, the greater number appear to have been reduced by having a succession of large flakes struck from them, which has caused them to assume a rudely spherical form. It is the same, M. de Cossigny remarks, with the smaller fragments. Sharp splinters abound, and even the most minute *débris* is made up of little flakes and splinters, pointed and cutting. These fragments, he has no doubt, have been derived from the breaking and flaking of the larger flints, and as they are never reduced to the state of sand, he is of opinion that they cannot owe their origin to the action of impetuous torrents of water. The clay is not exactly plastic, but dry, and rather hard than unctuous to the touch. M. de Cossigny thinks it has been deposited in the interstices between the stones by the muddy water derived from the wash of strata, the demolition of which supplied the flints. He is of opinion that the accumulation cannot possibly be the result of torrents, currents, or the waves of the sea, and he likewise shows that it cannot owe its origin to chemical action, after the manner of the "pipes," which are so frequent a phenomenon in Cretaceous regions, and which, as Mr. Prestwich and others have shown, are due to the percolation of acid water dissolving the chalk, and thus forming pipes and funnels into which the overlying sand, gravel, etc., gradually sink. Rejecting these and other explanations, M. de Cossigny has not hesitated to suggest that the phenomena of the clay with flints may be the result of glacial action—that it may be the *moraine profonde* which collected between the ice and the superjacent rocks all the material produced by the grinding of the glacier—the clay that envelopes the shattered stones being perhaps no other than a *boue glaciaire.* He points out that the appearances presented by the clay with flints are just such as would result from the action of a glacier, and that the absence of striæ from the flints is not any real objection to this view. All the circumstances were unfavourable for striation,—the homogeneity and equal hardness of all the stones which came into contact, their tendency to give way or flake immediately under pressure, their surfaces often rough and irregular with concavities and knobs that were obstacles to slipping. M. de Cossigny enters into further details to show that all the physical features presented by this remarkable accumulation are more readily explained and accounted for by a glacial hypothesis than by any other view of their origin. The overlying sands with flints betray the action of water; the flints are all more or less altered and discoloured, and their sharp angles have been removed. They are often indeed rounded. The deposit, according to Cossigny, is the result of torrential action. It is covered in turn by another sand-bed of much the same composition, but which contains here and there boulders of a Tertiary quartzose conglomerate, similar boulders being sprinkled over its surface. The position of this last bed shows that it was not laid down until after the other deposits had been much denuded,—until, in short, the surface had attained its present configuration. M. de Cossigny, as I have said, relegates all these deposits to the Tertiary Period, but the evidence upon which he relies is perhaps hardly conclusive. But whatever their age may be, it is certainly very remarkable to meet with accumulations of such a character in the low-lying regions to the south of Paris. Cossigny is of opinion that the glaciating agent, if such it were, must have come from the north, since there are no mountains or high-grounds in the neighbourhood of Paris from which glaciers could have flowed. But mountains are not necessary to the formation of an ice-sheet, neither are we compelled to infer that the ice was continuous with any great northern *mer de glace*. During a period of extreme glacial conditions it is probable that wide regions in the low grounds would be covered with massive sheets of snow and *névé* passing into glacier-ice, which would have a motion of their own. The dissolution of these local ice-sheets would give rise to more or less copious floods and torrents, to which we might attribute the origin of the sand with flints that overlies the older morainic accumulation. The more recent sand with erratics of conglomerate may pertain to some long subsequent epoch when fluvio-glacial conditions returned.[1]

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[1] *Nature*, vol. xiv. p. 179.

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[1] For accounts of these and similar accumulations, see Laugel: *Bull. Soc. Géol. France*, 2e Sér. t. xvii. p. 316; *Ibid.*, 2e Sér. t. xix. p. 153; Ebray: *Ibid.*, 2e Sér. t. xvii. p. 695; Hebert: *Ibid.*, 2e Sér. t. xix. p. 445; *Ibid.*, 2e Sér. t. xxi. p. 58; De Mercey: *Ibid.*, 3e Sér. t. i. pp. 134, 193; De Cossigny: *Ibid.*, 3e Sér. t. iv. pp. 230

In the maritime districts of Southern England and Northern France loose superficial accumulations attain a considerable development. They occur as more or less wide-spread coverings that vary in thickness from a few feet up to many yards, and extend from the sea-coast inland to a less or greater distance. They were long ago noticed by Dr. Borlase, who described their essential features, and since his time they have given rise to some interesting discussions as to their origin. In the south of England they are known under the general name of "head." They consist of a more or less coarse agglomeration of angular *débris*, and large blocks set in a matrix of earthy matter. Sometimes the "head" has an appearance of rude bedding, but not such as could be attributed to subaqueous arrangement. No included water-worn stones or pebbles, according to Mr. Godwin-Austen and others, are ever to be found. As a rule, the deposit is quite unfossiliferous, but Mr. Prestwich has detected in the sections of it which are exposed in the neighbourhood of Weymouth several land- and freshwater-shells. The stones and blocks are all of local origin, and have generally not travelled far. Some, however, have evidently been carried farther than others, but not a single fragment belongs to other drainage-areas than that in which any given mass of the "head" occurs. Mr. Godwin-Austen, to whom we are indebted for a very interesting and suggestive description of this peculiar formation,[1] reflecting upon the fact that no such accumulation is now taking place in the districts where it occurs, comes to the conclusion that the "head" has resulted from long-continued subaerial waste under severer conditions of climate than now obtain in regions bordering on the English Channel. To obtain such conditions he supposes the land to have been formerly elevated to such an extent as to bring the whole of the higher portions of this country into regions of excessive cold.

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675 ; J. Martins : *Ibid.*, 3e Sér. t. iv. p. 653 ; Collenot : *Ibid.*, 3e Sér. t. iv. p. 656 ; Delafond : *Ibid.*, 3e Sér. t. iv. p. 665 ; De Lapparent : *Ibid.*, 3e Sér. t. iv. p. 671.

[1] *Quart. Journ. Geol. Soc.*, vols. vi. p. 97 ; vii. p. 121 ; xii. p. 40.

Mr. Prestwich, who has also furnished geologists with an admirable account of the "head" as seen in the neighbourhood of Weymouth,[1] does not agree with "those who consider this an old talus, or with Mr. Godwin-Austen, who regards it as a talus formed at high altitudes under great cold." He points out that "if the deposit were a mere subaerial accumulation it would in all cases be in close connection with the slope or cliff supplying the materials, would dip from it at a high angle, and never be carried far beyond the range which that angle would subtend; whereas at Sangatte and Brighton, although the layers are turned up at a high angle against the old cliff, they are prolonged in a gradually diminishing angle to a considerable distance from it." Thus at Chesilton, where the escarpment is 400 feet high, the angular *débris* spreads over the ground to a distance from the base of the cliff of 1600 feet, which, as Mr. Prestwich remarks, is "very far beyond that to which any materials falling from the cliff, had it even been originally double the height, could possibly have extended." At Portland Bill this appearance is still more striking, for the angular *débris* in that neighbourhood extends south for a distance of nearly a quarter of a mile at the small angle of 4° or 5°. Such inclinations are so slight that we cannot but admit with Mr. Prestwich that they are quite insufficient to keep loose rubbish and rocks in motion; something more than the mere gravity of the stones was required to cause them to travel down slopes so gentle. Accordingly he tries to account for the phenomena by supposing that after the land had been subjected for some considerable time to the ordinary action of the weather, the low grounds bordering on the Channel were temporarily submerged, and that the "head" probably owes its origin to the inundations brought about during the subsequent more or less sudden emergence of the land. He infers, to use his own words, "that the emergence, at first gradual, was marked by short oscillations, which, according to their relative force and duration, swept down the soil with its land-shells and softer beds, alternately with the coarser materials and the bones of animals drowned by the inundation, spreading first one and then the other in irregular beds and lenticular masses; while the final emergence, more sudden and consequently of greater effect, swept down the overlying *débris*." "Or again," he says, "it is possible that a succession of waves caused by earthquake-movements may have swept at short intervals over the adjacent land."

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[1] *Quart. Journn. Geol. Soc.*, 1875, p. 29.

There are several objections which might be urged to this theory, not the least forcible of which is the fact that deposits similar in all respects to the "head" occur in many places which are far enough removed from the sea. They are forming now in the Rocky Mountains and other alpine regions. Thick sheet-like accumulations of angular blocks, *débris*, and rubbish, which are not of morainic origin, may be observed covering low grounds in the Southern Uplands and Northern Highlands of Scotland in places where they have long ceased to accumulate. I have referred to the limestone-breccias of Gibraltar, and to the general abundance of angular *débris* and drift in many regions where no such deposits are now taking place. If we consider the fact that during the height of the Glacial Period all Northern Europe was covered with a vast ice-sheet, and that at the same time snow-fields and glaciers existed in almost every hilly region not only in the central but even in the southern regions of our continent, we need have little difficulty in accepting Mr. Godwin-Austen's view that the "head" is due to the action of severe climatic conditions. The transport of the materials outwards from the base of the cliffs I would explain in the same manner as that of the angular *débris* which has travelled from the base of the Rock of Gibraltar and overspread the low grounds of Buena Vista and Rosia. Besides hard frosts, the "head" betrays the former action of *névé*, of melting snows and floods. It is quite in accordance with this view that we find on both sides of the Channel evidence of floating-ice during the Glacial Period. Several large erratics of granite, syenite, and other rocks, occur at Pagham, on the Sussex coast, which must have been transported to their present position by floating-ice coming from Brittany. And Dr. Barrois has described a coarse conglomerate at Kerguillé, on the shores of the latter region, which, according to him, could only have accumulated at a time when those maritime districts were some 10 mètres lower than at present, and when ice formed in the rivers and upon the coast of that part of France, and scattered along shore the various kinds of stone with which it was charged.[1] M. Tribolet, indeed, is of opinion that small glaciers actually existed in Brittany at that time,[2] and the large erratics noticed by Mr. G. Doe[3] and Mr. Pengelly[4] in Devon, some of which measure from 500 to more than 3800 cubic feet, also testify to a former severe climate. It is true that these erratics have not travelled far, but this only shows that they could not have been carried by icebergs. Bearing these facts in mind, and keeping in view the conditions which prevailed generally throughout Northern Europe and in all the hillier regions of our continent, it seems to me unnecessary to suppose with Mr. Godwin-Austen that the severe climatic conditions which produced the "head" on both sides of the Channel were brought about by an extreme elevation of the land. It is certain that at the time the "head" was formed the shores of England extended farther into the sea than now, for the deposit in question caps cliffs which are being assaulted by the waves. But we have no reason to believe that any such excessive elevation as would be required to carry up the low maritime districts of the Channel into regions of extreme cold has ever taken place. It is also well worth remembering that the regions in which the "head" occurs are just those districts which were never overflowed by the ice-sheet, and that consequently their subaerial deposits have been left undisturbed, while those of glaciated regions have been swept away; the loose *débris* which occurs in such countries as Scotland being merely the subaerial waste which has accumulated since the ice vacated the low grounds and vanished from the mountain-glens. The "head," therefore, is the representative, as Mr. Godwin-Austen has remarked, of the glacial deposits of the north.[5]

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[1] *Ann. de la Soc. Géol. du Nord*, t. iv. p. 186.

[2] *Ibid.*, t. v. (1878).

[3] *Brit. Assoc. Rep.*, 1876, p. 110.

[4] *Ibid.*, 1877, p. 85.

[5] For descriptions of "head" see Sir H. de la Beche's *Report on the Geology of*

It is interesting to note that in Cornwall, where the "head" is well developed, we encounter at the base of certain post-glacial deposits, to be described in the sequel, torrential gravels which are well known from the fact that they have been long worked to get at the lumps of tin-ore which they contain. This tin-bearing accumulation is composed of a confused mass of sand, gravel, pebbles, blocks, and boulders, some of which have weighed as much as 200 lbs. and upwards. It is just such a deposit as might have been formed by torrents more or less suddenly discharged from melting snow and ice. Mr. Ussher has shown that it is posterior in age to certain ancient raised beaches upon which the "head" reposes, and it is therefore of approximately the same age as the "head" itself. The latter, in short, will represent the angular *débris* moved forward by the action of frost, melting snows, etc., while the stanniferous gravels will denote that portion of the subaerial waste which was swept into gullies and stream-courses, and hurried along by the tumultuous waters of spring and summer.

With the cause or causes that induced the Glacial Period we are not at present concerned, but we may at least conclude from the facts so briefly set forth in this and the preceding chapter, that whatever the origin of the glacial climate may have been, it certainly cannot be attributed to any mere elevation of the land. The phenomena are much too general to be thus accounted for. Not only has Europe passed through its Glacial Period, but abundant evidence is forthcoming to show that North America has experienced similar climatic conditions. A great ice-sheet covered all the northern regions of that continent and flowed as far south as the latitude of New Jersey, and still farther south in Ohio, Indiana, Illinois, and Missouri. At the same time the valleys of the Rocky Mountains and the Sierra Nevada were filled with gigantic glaciers, compared with

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Cornwall, Devon, and West Somerset; and W. A. E. Ussher's papers on the "Recent Geology of Cornwall" (*Geological Magazine,* 1879), in which copious references will be found to other sources of information. The same writer gives a further account of "head" in his *Post-Tertiary Geology of Cornwall.*

which their modern representatives are the merest pigmies. Even in regions far south of the limits reached by the ice-sheet of the north, great deposits, and wide-spread sheets of angular *débris*, rock-rubbish, and coarse gravel, are found occupying positions where no such deposits are now taking place, and which cannot possibly have been formed under present conditions. Very often remains of an ancient soil, with leaves, fruits, and stumps of trees *in situ*, togther with elytra of beetles, squirrel-gnawed hickory-nuts, etc., are found buried under depths of 15 or 20 feet of these superficial accumulations in North Carolina, where they have been studied by the State Geologist, Mr. W. C. Kerr.[1] They often mask to a considerable extent the contour of the underlying strata, so that the present ravines are excavated partly in the superficial drifts, and partly "along or across the crests of the old buried hills and rocky ledges." Such is the general character of the gold-bearing beds which are extensively spread over the flanks and low ridges of the Uwharrie Mountains. Their position and the carry of their included rock-fragments, some of which have travelled six miles, shows that they must have descended from the mountains, "at whose bases or on whose lower and gentle inclines they are found." According to Mr. Kerr, the force which impelled them cannot have been water,—"neither are they moraines—accumulations at the base of descending ice-masses." They "have crept down the declivities of the hills and mountains," he says, "exactly as a glacier descends an alpine valley, by successive freezing and thawing of the whole water-saturated mass, both the expansion of freezing and gravitation contributing to the downward movement; and with each thawing and advance the embedded stones and gold particles dropping a little nearer the bottom. If these beds are followed down the slopes into the valleys and bottoms of the streams to the flood-plain, they will be found to have changed character with every rod of advance, all the gold having been dropped either on or near the foot of the slopes, the pebbles being more exclusively quartz, and more and more rounded, and accumulated in a stratum at the bottom of the bed, or constituting the whole of it."[1]

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[1] *Report of the Geological Survey of North Carolina*, vol. i. p. 156.

The glacial phenomena of Europe are, in short, reproduced in North America. Similarly it is well known that in Asia the valleys of the Himalaya formerly supported enormous glaciers, and that traces of ice-action occur in China in regions which are certainly very far from being glacial now. All this, as I have said, points to some widely-acting cause, a conclusion in which geologists are now pretty well agreed. But while I reject the view that the Glacial Period of Europe, or of any portion of Europe, was directly induced by an elevation of the land, I do not doubt that here and there the intensity of glaciation may have been locally influenced in some measure by changes in the relative level of land and sea.

Hitherto we have confined our attention to phenomena which are more or less directly due to the action of frost, of snow, and glaciers. We must now glance for a little at the general character of those aqueous deposits which we have every reason to believe were accumulated upon certain areas in the low grounds of Europe contemporaneously with the erratics, moraines, and angular *débris* of other districts. And among these must be included those angular gravels in the southern districts of England, which have been described and explained by Mr. Darwin. The fact that perennial snow and ice were so widely distributed over the northern latitudes of our continent, and that so many of the hilly regions, even in the extreme south, supported large glaciers, sufficiently proves that during the Glacial Period the winter must have been severe, but it also indicates the prevalence of great humidity. There must have been excessive evaporation, and a more copious distribution of moisture, over the length and breadth of our continent than is now the case, for many of the regions which were formerly covered with perennial snow have at present a very small rainfall. It is, therefore, to say the least, not improbable that during the Glacial Period the amount of heat received from the sun in summer may have been as great or even greater than it is now in that season ; in other words, the seasons may have been more strongly contrasted than they are at present—less heat reaching our latitudes in winter, but more in summer, than is now the case. The summers in Central and Southern Europe were probably very humid, and the abundance of snow and ice upon the mountains would tend to chill the air, so that although more heat may have been received directly from the sun, it is doubtful whether the climate during the warm part of the year would be, upon the whole, as genial as it is with us. Upon the mountains and in the regions covered by the ice-sheet, a large proportion of the moisture would be precipitated in the form of snow. Notwithstanding this we cannot doubt that in summer there would be copious rain, while enormous quantities of snow would be melted, and the rivers flowing from the ice-sheet and the local glaciers of the mountain-regions would be swollen to a prodigious degree. We might, therefore, from such considerations expect to find abundant traces of floods and inundations over all the low grounds of Europe to which the swollen rivers could find access. M. E. Collomb has made some interesting calculations which serve to give one some faint idea of the volume of water discharged from the glaciers of the Ice Age.[1] These calculations are based upon the observations of MM. Dolfus and Desor on the Aar glacier in 1844 and 1854.[2] These glacialists found that the amount of water discharged from this glacier between 20th July and 4th August averaged 1,278,738 cubic mètres daily—the minimum being 780,000 cubic mètres, and the maximum 2,100,000 cubic mètres. The area occupied by the glacier is estimated at 52 square kilomètres. Now, supposing that the old glacier of the Rhone (the area of which

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[1] Mr. Kerr's explanation of these superficial phenomena, it will be observed, does not differ greatly from that adopted by Prof. Ramsay and myself to account for the origin of the Gibraltar breccias. When our paper was written we did not know of Mr. Kerr's investigations in this matter, otherwise we should have made special reference to them.

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[1] *Comptes Rendus de l'Acad. des Sciences* (1868), t. lxvii. p. 668 ; *Cosmos*, t. iii. (1868) p. 407.

[2] Agassiz : *Nouvelles Études sur les Glaciers*, p. 370.

M. Collomb estimated at 15,000 square kilomètres, but which is actually under the truth) discharged its water at the same rate, it must have yielded a daily supply of 605 millions of cubic mètres. But if it be true, as all the facts would lead us to believe, that in the summers of the Glacial Period more heat was received directly from the sun,—then the daily discharge from such a glacier must have been greatly in excess of that amount.

The rivers which escape directly from a glacier are invariably turbid and discoloured with the fine mud which they hold in suspension, this sediment being derived from the pounding and grinding of the rocks under the moving ice. MM. Dolfus and Desor found that a litre of water from the Aar glacier contained 0·142 gram. of fine mud, so that according to Collomb's estimate of the area and daily discharge of the ancient Rhone glacier, the water escaping from the latter must in summer time have transported 86,000,000 kilogrammes, or about 8500 tons (English) per diem—an estimate which, considering the circumstances already referred to, is probably much under the actual truth.[1]

Bearing all this in mind, we are prepared to learn that traces of water-action should be met with at very considerable heights

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[1] According to Helland the quantity of mud in the rivers that issue from the glaciers of Greenland is very variable, as may be seen from the table given by him, which is as follows:—

		Grams. of mud in 1 cubic mètre of water.
River of the glacier of Jakobshavn	July 9, 1875	104
,, ,, Alangordlek	,, 10, ,,	2374
,, ,, Ilardlek	,, 17, ,,	723
,, ,, Tuaparsuit	Aug. 6, ,,	678
,, ,, Umiatorfik	„ 20, ,,	75
,, ,, Assakak	,, 21, ,,	208
,, ,, Rangerdlugssuak	„ 11, ,,	278

Similar observations by the same geologist on the water issuing from the snow- and ice-field of Justedalsbræen likewise showed that the quantity of mud varied in the different streams, and even in the same river. The result of ten different observations in the months of June and July gave a mean of 147·9 grams. of mud in 1 cubic mètre of water.—See *Quart. Journ. Geol. Soc.*, 1877, p. 157; *Om de isfyldte Fjorde og de glaciale Dannelser i Nordgrönland*, p. 53; *Geol. Föreningens i Stockholm Förh.*, Bd. ii. No. 7.

in all the great valleys that hold communication with snow-covered mountain-regions, and not only so, but that vast quantities of muddy deposits should be met with in places where the form of the ground is such as would admit of quiet deposition from inundating waters. Those great deposits of löss which cover such extensive areas and reach to such heights in the valleys of the Garonne, the Rhone, the Saône, the Seine, the Rhine, the Danube, the Theiss, the Drave, the Save, and other rivers flowing from the mountains of Central and Southern Europe, represent the mud borne down by the great inundating waters that escaped from the ancient glaciers. But the accumulations which are known under the general terms of löss, lehm, brick-earth, etc., have not all been formed in the same way. Some are the result of mere subaerial waste—others have arisen from the chemical action of acidulated water upon Cretaceous strata—and superficial beds like these must frequently have been re-arranged, redistributed, and often washed down from higher to lower levels by rain and melting snow. It is not necessary, therefore, to suppose that every high-level accumulation of loam, silt, or clay, such as much of the brick-earth of Northern France, is of fluviatile origin. The severe winter frosts of the Glacial Period would penetrate some depth into the ground, and tend to disintegrate the rocks and render these more easily assailable by rain and melting snow. During spring and summer much water would be set free, and quantities of silt and loam would be transported down the slopes to accumulate in the hollows and depressions. And in regions where the rock-bottom was composed of the same strata throughout, the superficial accumulations taking place at the surface would naturally assume a great sameness of character.

But we cannot so account for the presence of the wide and deep masses of löss which characterise such valleys as those of the Rhine and the Danube. The considerable elevation attained by the deposits in question, and their vast extent, have led many geologists to believe that they could not have been laid down by flooded rivers, and an outline has been given (Chapter

IX.) of some of the more noted hypotheses which have been advanced to explain the phenomena. The old lacustrine theory has been generally abandoned, and the view advocated by Lyell has likewise proved insufficient. It is quite clear, in fact, that the theory, which shall ultimately be accepted, must take cognisance of all the more widely-spread loamy deposits described in Chapter IX. We cannot have a special explanation for the löss and lehm of each particular region. They evidently pertain to one and the same period, and must owe their origin to some widely-acting cause or causes. They occur in so many different regions that we are precluded from supposing that elevations and depressions of the land can have had anything to do with their formation. Do they owe their origin then to aqueous action, or can they be the result of great dust-storms as Baron von Richthofen maintains? The former of these views appears to me to harmonise most closely with the evidence, and the great bulk of the loamy deposits I would assign in common with the majority of glacialists to the action of vast inundations. I do not, however, deny that here and there the löss and other aqueous deposits pertaining to the Glacial Period may have been subsequently modified by the action of wind, but I can find no evidence which would lead me to suppose that any of our widely-spread sheets of löss have been accumulated by storms of wind transporting the finely-sifted materials from dry central regions. Some of the principal objections which may be urged against Richthofen's theory I shall presently specify, but, meanwhile, what I take to be the actual origin of the loamy deposits will first be set forth, and as shortly as possible.

According to Mr. Prestwich there are cogent reasons for believing that the loam of the plateaux and upper slopes of the valleys of Northern France have been laid down contemporaneously with the high-level gravels. The loams in question are in short flood-deposits, which were accumulated at a time when the rivers flowed at a much higher level than they did in subsequent ages. I believe the same rule holds true for all the great river-valleys of Europe, and that we are not called upon to suppose that the vast sheets of Rhenish and Danubian löss only began to be accumulated after the valleys had been excavated to their present depths. These deposits are the results of the great floods that took place doubtless at stated times all through the Glacial Period—those at the higher levels having been laid down at a much earlier date than the loams which we find overlying the low-level gravels towards the bottoms of the present valleys. But even with this consideration in view we are under the necessity of inferring the former frequent occurrence of floods and inundations, which it would be hard to parallel at the present day. I have referred to the suggestion made by my brother, and to the view supported by Mr. Belt, that when the great ice-sheet extended south as far as the latitude of the Thames, the large rivers that flowed north from Central Europe would be dammed back so as to inundate vast areas, which might thus become overspread with glacial mud. It is hardly possible to escape from this conclusion. But even without any such dam to the passage of the water northward, the valleys of the Rhine and similar rivers must have been filled to overflowing. The waters pouring in at the upper ends of these valleys, supplemented by the torrents and floods received from tributaries, and the water derived from melting snow on the low grounds and from excessive rains, could not escape at once in a great tumultuous current. The rivers frozen over in winter would themselves tend to choke a passage to the north, just as is the case with the great rivers of Siberia at present. Thick ice might continue to bind them in the north for some time after their icy covering had melted in the south : and wide areas in the upper reaches of the valleys would thus become inundated. Again, if we consider the enormous quantities of water which would be discharged from the melting snows in spring and summer, we must see that the valleys themselves would be insufficient to carry these waters immediately away. Even in our own little country we may observe how after unusually heavy rains all the rivers rise in flood, and wide areas become inundated ; and this inundation-water is not a tumultuous raging torrent, but very frequently assumes the aspect of a wide lake-like expanse of quiet water, from which fine sediment is deposited, forming a film of mud more or less continuous. It is only here and there that we observe coarse sand and gravel strewn over the fields to mark the course taken by the thread of the current, which eventually succeeded in draining the flooded area.

The homogeneous character of the Rhenish and Danubian löss is well explained by this theory of its origin. Composed in chief measure of the fine silt derived from the glaciers of the Alps, it is not surprising that it should show such a sameness in all the great valleys which were charged with water descending in vast volumes from the glaciated areas. The waters of the Rhine invaded the lower reaches of most of its tributary valleys, and deposited there the same kind of mud as that which accumulated in the main line of drainage. But farther up these lateral valleys the mud would assume more of a local character, composed as it would be of materials derived from the disintegration and denudation of the adjacent rocks. In other regions, such as the plateaux of Northern France and the low grounds of Southern England, mud and silt would likewise be widely distributed, but these would be derived chiefly from the wash of the Cretaceous and other strata by rain, by the water coming from melting snow, and in the valleys doubtless by deeply-flooded streams and rivers. But it is in those regions that drained more or less directly from glacier-regions where we find the deepest and broadest accumulations of loamy deposits. The Garonne was flooded by the melting snow and ice of the Pyrenees, the Rhone by the waters coming from the vast ice-fields of the Alps, the Saône by those derived from the Jura, the Seine by the dissolving snow and ice of the Morvan and neighbouring hilly tracts. Muddy inundations likewise choked many of the valleys of the Carpathians, and a like fate befell such valleys as those of the Drave and the Save that received the drainage of the Eastern Alps. On the south side of the Alps there was no space for the accumulation of silt. The muddy waters carried down vast quantities of gravel and shingle, but the finer materials were swept right out to sea. It will of course be understood that in all the river-valleys of Central Europe enormous sheets of gravel and shingle were swept along the bottoms of the valleys, the löss only accumulating in places where the inundating waters were comparatively tranquil.

The occasional occurrence in the löss of sporadic stones and boulders, which are sometimes striated, points to transportation by river-ice ; and the presence of lines of gravel and sand, which here and there have been observed, indicate unquestionably the action of water ; and the same may be said of such alternations as those described by Dr. Nehring which occur at Thiede and Westeregeln, and of the bedded löss of Heiligenstadt, near Vienna, referred to by Dr. Jentzsch. Again, at Nussdorf and Hungelbrunn, in the same region, the löss, according to Th. Fuchs, contains freshwater-shells in a distinct bed ; at Nussdorf the bed was a bluish-green silt with *Hypnum,* while at Hungelbrunn it was a white marly deposit. Such instances of stratification, however, are not common in the löss, which, like the flood-deposits (mud and silt) of rivers such as the Mississippi and the Ganges, generally shows little or no trace of bedding. The calcareous concretions of the löss also find their counterparts in the recent alluvia of the same rivers. The origin of the vertical capillary structure is less easily accounted for. Some writers believe that the minute tubes represent grasses and other plants which were gradually buried as the löss accumulated about them. But I am not aware that any trace of vegetable matter has ever been found in the tubes, and the capillary structure, like the concretions, may be of inorganic origin. Chemical analyses, at all events, have shown that löss contains little or no organic matter, which we might have expected to meet with in much greater abundance had plants given origin to the innumerable vertical pores which are so commonly present in the typical deposit of the Rhine and the Danube.

The character of the shells and other organic remains found in the löss is quite in keeping with the theory which attributes that deposit to the action of muddy inundation-waters, a view which is strongly supported by Professor F. Sandberger and others who have made a special study of the question. The shells, as Sandberger has shown, bespeak colder conditions of climate, and belong to species which for the most part occupy damp and shady places. They are just such forms, indeed, as may have lived in woods and meadows near the borders of streams, rivers, and lakes, and which therefore would be liable to be swept away during floods and inundations. Moreover, they probably represent only a fraction of the terrestrial molluscous fauna of the period. Thus in the lists given by F. Sandberger, A. Braun, Gysser, Leydig, and Heynemann, of shells obtained from the löss of the valleys of the Main, the Neckar, and the Upper Rhine, there is only one freshwater-shell (*Limneus truncatulus*) to some eighteen species of land-shells. Dr. Sandberger tells us that in the mud brought down by the flood-waters of the Main on February 19, 1876, he observed 52 species of shells, namely—land-shells, 38 species ; freshwater-shells, 14 species. The contrast was still more striking when the numbers of individuals were taken into account. Thus, while freshwater-univalves and bivalves numbered only 69 individuals, the land-shells were no fewer than 10,747. The species which were most abundantly represented were as follow :—

Helix pulchella and *H. costata* .	4228	examples.
Pupa muscorum . . .	3550	„
P. pygmæa	654	„
Cæcilianella acicula . . .	596	„
Cionella lubrica . . .	574	„
Chondrula tridens . . .	209	„

The smaller species are thus by far the most abundant in the inundation-muds of the present day, just as they are in the old valley-löss. The wide diffusion of these forms in the löss offers no difficulty. Their extreme lightness would insure their dispersion to great distances. Even larger species might under certain conditions be transported a long way. Captain Feilden, for example, tells us that in the autumn of 1874, after a long continuation of rainy weather and north-west winds, he found in sheltered coves on the coast of Malta, facing the island of Sicily, great numbers of land-shells, which were certainly not indigenous to Malta. "On examination they proved to be all dead shells, plugged at the mouth with a tenacious blue clay which converted them into floats. These had doubtless been washed down by the flooded rivers of Sicily, and discharged in vast numbers into the Mediterranean. The prevalent north-west winds had wafted them, along with fragments of pumice-stone and broken reeds, to the coast of Malta."[1]

The mammalian remains characteristic of the löss belong to the northern group, and accord perfectly with the facies of the mollusca. They betoken decidedly colder climatic conditions than are at present experienced in Central Europe, and may quite well have subsisted in regions exposed to severe winter cold and considerable humidity.

The conclusion we come to, then, is simply this, that the löss of the great river-valleys of Central Europe is merely the flood-loam of the Glacial Period. The upland- or hill-löss belongs upon the whole to an earlier date than that which is found within the valleys themselves. It is the inundation-mud which was laid down by the rivers when they flowed at higher levels. After these rivers had succeeded in deepening their beds sufficiently, their flood-waters were unable to overflow upon the plateaux, and the deposition of löss was then confined to the valleys themselves. The löss and the ancient river-gravels are therefore, as Mr. Prestwich has maintained, merely terms of one and the same series.

Hitherto I have spoken only of the flooded rivers that descended from alpine regions; but what about the water which must have escaped from the ice all along the borders of the massive *mer de glace* which extended in Germany down to the 50th parallel of latitude? It is extremely probable, nay, I will even venture to say, certain, that a very large proportion of the water derived from the melting of that ice-sheet in Northern Europe, would find its way by underground channels along the natural slope of the ground into the Polar Ocean and the basins of the Baltic and the North Sea. The phenomena of the till have disclosed the fact that streams and torrents flowed underneath the ice, the general course of which, however much it might be influenced by the obstruction of the overlying ice, would nevertheless tend to follow the inclination of the ground. There would thus be many large sub-glacial streams and rivers running in directions quite opposed to that of the *mer de glace.* The sub-glacial representatives of the Messen and the Dwina, for example, would flow directly into the Arctic Ocean ; those of the Düna, the Nieman, the Vistula, the Oder, and other North German rivers, would go by way of the Baltic and the North Sea, as would also those of Sweden, Southern Norway, and East Britain. And thus I would infer that the water escaping into North Germany from the ice-sheet, however actually copious it might be, would yet be relatively small in amount. It would in fact be derived chiefly from the superficial melting of the ice-sheet. It is quite true that there would be an abundant flow of water all over the surface which would tend in the direction of the ice-flow ; but much of it we may suppose would disappear in crevasses, or into such great holes as Nordenskiöld observed in the inland-ice of Greenland.[1] So far as we know from observation, the quantity of water pouring from the surface over the terminal front of the Greenland ice is much less considerable than that discharged by such glacial rivers as the Mary Minturn described by Kane.[2] This river flows all the year round, but becomes greatly swollen in summer. The superficial streams, on the other hand, are sealed up at night in summer, and in winter they vanish entirely. Then, again, we must remember, that the water flowing upon the *mer de glace* would be distributed in myriads of little channels, which would have no permanency, while that underneath the ice would tend to collect into larger currents which might keep an open course for themselves for long periods of time. Thus the water pouring off the surface of the ice would descend upon Germany in innumerable cascades, but would seldom or never discharge at any one point such enormous floods of water as those carried north by rivers coming from regions of alpine snows and glaciers. Moreover, we must remember that it would be comparatively pure water—it would hold in suspension an infinitely less amount of sediment than such rivers as the Rhine or the Danube. But the case would be very different with the water flowing out from under the ice-sheet in Russia. A glance at the map of Europe (Plate D) will show that a very large section of the extensive area which is drained by the Dnieper, the Don, the Volga, and their numerous affluents, was covered by the *mer de glace*. The ice-sheet flowed out of the Gulf of Finland, ascended the long slopes that drain towards the Baltic, crossed the water-parting, and thereafter pressed forward for a distance of not less than 300 miles in the direction of the Black Sea. South of the water-parting referred to, the sub-glacial drainage would therefore be in the same general direction as the present rivers. Consequently we should expect to find in Southern Russia abundant evidence of vast inundations—inundations on a much grander scale than any that could possibly have taken place in Middle and Western Europe. Large rivers and innumerable torrents, laden with glacial mud, would issue from the terminal front of the ice-sheet, and literally deluge the gently-undulating ground and low flats and plateaux which extend south to the Black Sea and the Caspian. In winter the waters would be greatly reduced in volume, while the rivers to the south of the ice-sheet would doubtless be frozen over. Snow might then gather over extensive areas in what are now the Steppes, and here and there be swept by violent winds into great heaps and wreaths, just as is the case at present in those regions and the tundras. When spring returned such wide sheets and hummocky masses of snow would begin to melt more or less rapidly, and thus add their quota to the vast volumes of water that poured southwards from the terminal front of the ice-sheet.

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[1] *The Zoologist*, May 1879.

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[1] *Geological Magazine*, vol. ix. p. 360.

[2] *Arctic Explorations : The Second Grinnell Expedition in Search of Sir J. Franklin*, vol. i. p. 97.

Now it is precisely in the low-lying regions of Southern Russia that we encounter the most extensive deposits of loam in Europe. They form the subsoils of the Steppes—those vast grassy plains which, within the drainage-area of the Don, the Dnieper, and the Volga, comprise nearly 200 millions of acres. The soil is generally a more or less rich dark or black loam which yields heavy crops when it is cultivated, and which would no doubt support an abundant forest-vegetation were it not for the great droughts of summer, which scorch the ground and forbid the approach of trees; the principal vegetation of the Steppes, in short, consists of grasses which often grow to a height of five or six feet.

Murchison and his colleagues, in their great work on the geology of Russia, were of opinion that the black-earth of the Steppes may have been to some extent "derived from the destruction of the black Jurassic shale, so uniform in its colour over all Northern and Central Russia." They also pointed out, in proof of the correctness of this inference, the suggestive fact that the black-earth is absent to the south of certain tracts where there is reason to think the black Jurassic shale never existed. "In truth," they remark, "the black-earth is in this respect exactly like the Northern Drift of Russia, which invariably contains many materials of the formation immediately north of it." According to the same authors it is wholly unfossiliferous, but chemical analyses show that it contains organic matter and traces of humic acid. Goebel states that he detected vegetable *débris* in the black-earth, but the specimens examined by him appear to have been taken from the surface, which may also account for the quantity of carbonate of lime found by him—a substance which, according to other analyses, would appear usually to be wanting in the black-earth. Bischoff is of opinion that the view held by Murchison and his associates is very probably correct, inasmuch as the black

Jurassic shale contains a large amount of bituminous matter, which would account reasonably enough for the considerable percentage of organic substance met with in the black-earth. It is not improbable, however, that here and there the blackness of the earth may have arisen from the decomposition of grasses and other plants. But if this were so, it is strange that traces of vegetable *débris* should appear to be so completely absent from the deposit. The absence of plant-remains, however, is quite in keeping with the non-appearance of shells or animal relics of any kind, and is readily explicable on the theory of the aqueo-glacial origin of the black-earth. It is hardly likely that either plant- or animal-life would be well represented in those low-lying regions of Southern Russia which were liable to be more or less completely inundated every spring and summer, and which in winter must have experienced an excessively cold climate.

The black-earth would appear never to reach the great thickness attained by the löss of the Rhine and the Danube. This is what we might have expected from the configuration and position of the regions over which it is distributed. The wide open valleys and broad plateaux would not permit of the same heaping-up and ponding-back of the flood-waters as must have taken place again and again in Central Europe. The route to the south lay open, and the inundation-waters would thus be drawn off more rapidly than if they had been discharged in a northerly direction, where the outflow was impeded not only by the presence of glacier-ice, but by the freezing-over of the rivers themselves.

Some geologists have suggested a marine origin for the black-earth, but no one has ever succeeded in discovering in this deposit a single trace of any marine organism. And those who hold that the Northern Drift with its large erratics has been transported southwards by means of icebergs and currents are equally at a loss to account for the sudden disappearance of boulders not far from the northern limits of the Steppes. If icebergs during the Glacial Period sailed over the watersheds of the great rivers that flow into the Black Sea and the Caspian, and even floated for some 300 miles farther south, why should their journey have been so suddenly arrested? Why should not they be scattered over the whole breadth of the Steppes, or disclosed to view in the beds of the numerous rivers by which those wide regions are intersected?

In the foregoing remarks upon the origin of the löss and other loamy deposits pertaining to the same or approximately the same period, I have dwelt upon various phenomena which seem to me to bear strongly against the wind-theory advanced by Richthofen. There are many other objections which might be urged to that view, but I shall specify only one or two.

1. The physical conditions of our continent during Pleistocene times would not permit of the existence of a desiccated central area, like those arid deserts of Asia referred to by Richthofen. The löss unquestionably forms part and parcel of the glacial accumulations, and the climate at the time of its deposition, as its shells alone prove, must have been not only colder, but more humid than the present. Even if Europe generally had stood at a higher elevation then than now, still that could not have converted any part of our area into a dry desert. In point of fact, as we shall see in the sequel, genial and humid conditions prevailed generally throughout Europe at a period when the land stretched considerably farther into the Atlantic, the British Islands then forming part of the Continent, and the area of the Mediterranean Sea being considerably reduced. The dry sandy tracts of Central Asia and of the great basins and plains in the Western Territories of the United States have no analogues in Europe. We have nothing here comparable with the phenomena of wind-erosion described by Mr. Clarence King and others as characteristic of the sandy plains of Western America, where the wind has undercut and gradually demolished masses of rocky strata by the filing action of the sand driven before it. Mr. King informed Mr. Pumpelly that the prevailing westerly wind, carrying sand, has carved and polished the rocky crest of the Sierra Nevada, and formed long

"wind-stream deltas" which extend as lofty sand-ranges from each pass in the mountains eastward far out on the desert.[1] If we except the dunes of our coast-regions, the only considerable areas of wind-driven sand which occur in Europe are those of Olkucz, Schiewier, and Ozenstockau in Poland, around which stretches a seemingly boundless wilderness of shifting sand. During storms this sandy plain appears like a tumbling and rolling sea, the sand-hills rising and dipping like the waves of the ocean.[2] These sands are part of the Northern Drift, and were deposited by the flood-waters descending from the *mer de glace* at the time of its retreat. Occasionally, also, in the Russian Steppes patches of drifting sand appear, and doubtless there are many other sandy tracts in Europe which might drift under the action of the wind were they not fixed by vegetation. But these expanses of sand have not been transported by wind from one part of the Continent to another. Most of them are flood-deposits of the Glacial Period, while others represent the lake-bottoms and sea-beds of Tertiary times. They are, in short, proofs rather of former humidity than aridity.

2. The geographical distribution of the löss is incomprehensible on the supposition that it owes its accumulation to the action of wind. Why should it occur so commonly in the valleys, and die off upon the plateaux? And why, as Dr. Jentzsch has asked,[3] should it be wanting in the Erzgebirge, the Thüringerwald, and other hilly districts of Middle Germany, while the regions on either side are more or less thickly covered with it? The same geologist refers to the occurrence of that narrow zone of löss which fringes the southern borders of the Northern Drift in Northern Germany, and in places attains a considerable thickness; and he asks how it is possible to believe that dust-storms could have worked only within that narrow zone. In point of fact the distribution of löss in Europe bears no relation whatever to the track of prevalent winds. On

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[1] *Amer. Jour. of Science and Arts*, vol. xvii. (1879), p. 139.

[2] Naumann's *Geognosie*, Bd. ii. p. 1173.

[3] *Verh. der k.-k. geol. Reichs.* (1877), Bd. xxvii. p. 254.

the supposition of its æolian origin, we should be compelled to believe that the winds blew outwards in all directions from the mountain-regions, and were careful to confine themselves as much as possible to the valleys; we should further be forced to conclude that they accumulated löss just in those very areas which were liable to inundations of muddy water during the Glacial Period, and that at the same time they neglected to strew with dust those particular districts in which, for many good reasons, glacial mud could not be deposited.

3. The mammalian remains in the löss do not indicate a dry climate. It is true, as Dr. Nehring has shown, that the fauna of Thiede and Westeregeln has a prevalent steppe-character, but commingled with pouched marmot, marmot, pika, jerboa, and other animals characteristic of the Steppes occur hyæna, lion, lemming, Arctic fox, reindeer, mammoth, and rhinoceros. These, it is true, are represented by only a few remains, while relics of the true steppe-fauna abound; but mammoth and woolly rhinoceros, reindeer and other northern and cold-temperate forms, are the most common forms met with in the löss generally, and we cannot, therefore, look upon their occurrence at Thiede and Westeregeln as exceptional. The presence of lion and hyæna does not militate against this view. These carnivores may have lived wherever their prey was in sufficient abundance. A dry and dust-covered country, with a climate like that of the Russian Steppes, does not seem essential to the wants of the jerboas, pouched marmots, marmots, and pikas, which are now met with in those places. These animals certainly endure the aridity of summer and the cold of winter, but there is apparently nothing in their habits or constitution that renders them unfit to live in regions of greater humidity. At a time when what are now the Steppes of Russia and the low grounds of the Rhine and the Danube were liable to be inundated for months every year, many animals which are now widely distributed over temperate and boreal regions would necessarily be restricted in their range; and not only so, but species that now occupy different provinces must formerly have lived in one and the same region. The

association of a steppe-fauna with reindeer, mammoth, hyæna, etc., at Westeregeln and Thiede is by no means singular. A similar mixture of species has been recorded from many other places in Central and Western Europe.

Such are some of the general considerations which might be urged against the ingenious theory so ably set forth by Baron von Richthofen. When we descend to details objections crop up at almost every step, and some of these have been well stated by Dr. Jentzsch in his paper already referred to. But as the inapplicability of Richthofen's theory is implied in the description and explanation of the European löss given in this and a preceding chapter (pp. 143 to 168), I may spare the reader further controversy.

I have now traced in meagre outline the principal physical phenomena which would seem to have characterised the Glacial Period at its climax. All Northern Europe down to the valley of the Thames in England, and to even a lower latitude in Germany, was covered with an ice-sheet, the terminal front of which, as we gather by following the limits reached by the morainic *débris* in Poland and Russia, gradually turned away to the north-east and north, passing by Nijnii Novgorod and Nikolsk, sweeping round the upper reaches of the Vichegda river, and thereafter striking north-north-west to the Tchesskaja Gulf. The limited extension of the ice-sheet in an easterly direction was doubtless due to the smaller snowfall in those regions, just as was the case during the Glacial Period in the comparatively rainless tract between the Missouri and the Rocky Mountains. But the greater humidity and cold are evinced by the presence in the Urals of moraines which tell of the former presence of glaciers where now there are none. At the same time the Alps and all the considerable hilly tracts of Central Europe supported *mers de glace*, many of which flowed out from the mountain-valleys, and advanced to almost inconceivable distances upon the low grounds. Even within the Mediterranean region glaciers of considerable size existed in valleys where no perennial ice now appears. The winters were so severe, that the rocks at levels and in latitudes where at present the temperature rarely or never descends to the freezing-point were broken up, fractured, and displaced, and long trains of coarse angular *débris* gathered upon the hill-slopes, from which *névé* and melting snow and torrents carried them down to the plains and caused them to overspread wide areas. Everywhere the forces of denudation were energetically at work. In summer the valleys were filled to overflowing with vast floods discharged from melting snows and glaciers. Enormous stretches of low ground, especially in Southern Russia, were converted into broad inundation-lakes, from the muddy waters of which an abundant precipitation of fine sediment took place. All these facts compel us to admit that the climate of Europe during the Glacial Period experienced a general refrigeration. The winters were unquestionably more severe, but we are not to suppose that the conditions were equally extreme throughout the Continent. The northern latitudes and the higher elevations were then as now subject to keener cold than the lower-lying and more southern regions. The temperature of the air in summer would be kept low by the presence of the great snow-fields and glaciers and ice-cold rivers and inundation-waters, so that although the heat received directly from the sun during that season may have considerably exceeded that which reaches us now, still the climate would not be such as to encourage the growth of a temperate flora in Central Europe. Looking at the physical conditions which then obtained in our continent, we may reasonably infer that the only flora which could have occupied Central Europe during the climax of the Ice Age must have been the Arctic willows and dwarf birches, the mosses, lichens, and saxifrages, which are now banished to mountain-heights and high latitudes. The pines and firs which adorn so many of our alpine regions must have descended then to the low grounds at the base of the mountains, while the great body of the temperate flora—the oaks, beeches, elms, poplars, etc., with their humbler congeners—driven in large measure from the latitudes which they now characterise, would spread into more southern climes. It would be with the animals as with the plants. Arctic, northern, and alpine forms—reindeer, musk-sheep, gluttons, marmots, tailless hares, and others no longer able to live in countries and districts which were permanently sealed in snow and ice—would advance towards the south, and, leaving the upper parts of the Alps and other mountain-ranges, would come down to inhabit the low grounds. The land-molluscs we should expect would also be compelled to "migrate;" so that when the cold had reached its climax and rivers were overflowing ever and anon wide areas in Middle Europe, the waters would sweep away groups of land-shells differing considerably from those that now tenant similar positions in the same latitudes. They would comprise many forms that are, in our day, confined to high elevations and more northern regions, while the general facies of the species would bespeak a colder and more humid climate.

Let me now ask the reader to recall the account given in Chapters III. and IV. of the fauna and flora of Pleistocene times. He will remember that distinct evidence was there adduced to show that during some part of the Pleistocene Period such a distribution of animals and plants as I have briefly indicated above did actually obtain. We found that reindeer and musk-sheep were at one time occupants of Southern France, that the woolly elephant lived in Spain and Italy, that the glutton frequented the shores of the Mediterranean, that marmots and tailless hares came down to the low grounds in Corsica, Sardinia, and Northern Italy. I also mentioned the fact that traces of an arctic flora had been met with at various points in the low grounds of Central Europe, that pines and other trees of northern and alpine habitats formerly grew upon the plains of France in the latitude of Paris, and that the Cembran pine, now a native of the higher Alps, descended to the low regions of Piedmont. Again we found that the land-shells of Central Europe in Pleistocene times implied climatic conditions which strongly contrasted with those of the present, and their evidence pointed in the same direction as that of the mammalia and the land-plants. In all this we see that the Pleistocene Period and the

Ice Age are closely bound together, so much so as to lead to the conviction that the latter can be nothing less than merely a stage or phase of the former. All the evidence, palæontological and physical alike, points in this direction, and assures us beyond the possibility of any doubt that the advent of an arctic flora in Central Europe, and of reindeer and musk-sheep, etc., in Southern France, coincided with the appearance of a vast *mer de glace* in Northern Europe, and with the great extension of glaciers in Switzerland and other mountainous regions in the middle and southern portions of our continent. And since we know that Palæolithic man lived with the northern mammalia while they were in occupation of low latitudes in Europe, we must perforce admit that man was certainly contemporaneous with the Glacial Period.

But it will not be forgotten that the Pleistocene Period was also marked during one of its phases by extremely genial conditions, when southern species of plants advanced far north of their present range, and when hippopotamuses, elephants, rhinoceroses, and other southern forms, commingled in North-western Europe with a group of mammalia like that which characterises the present more temperate latitudes of our continent. Furthermore, we found reason for believing that cold climatic conditions prevailed towards the close of the Pleistocene Period. It is from a consideration of the facts upon which these conclusions are based that many geologists, particularly in France and Germany, have concluded that the Pleistocene Period began with a mild and genial climate, which gradually became deteriorated, until eventually it was brought to a close with the Ice Age. They therefore maintain that Palæolithic man and the Pleistocene mammalia belong to preglacial and glacial times. In England, on the other hand, the views which were, and perhaps still are, generally held by geologists, differ in essential respects from those of many Continental writers. English geologists quite admit that Palæolithic man may have lived in North-western Europe in preglacial times, although they think this has not yet been demonstrated. But many, following

Prestwich, have strongly maintained that the ancient river-drifts which occur in the south of England (and by implication those of the north of France also) must be of postglacial age, since in some places the English deposits have been proved by superposition and other tests to be of later date than a particular boulder-clay in East Anglia. Which, then, of these two apparently conflicting views is true? It cannot be denied that certain ossiferous and implement-bearing beds in England are younger than the boulder-clay or morainic material they rest upon; but, on the other hand, it is a fact equally beyond question, that relics and remains of Palæolithic man, together with bones of the extinct and no longer indigenous mammalia, have been met with in and underneath the löss or ancient flood-loams of the Glacial Period. Did Palæolithic man inhabit North-western Europe before the advent of the Ice Age, and, surviving all the chances and changes of that period, did he live on in our continent after the severity of the climate had disappeared and given place to conditions which enabled the hippopotamus to range as far north as Yorkshire? These queries I will now attempt to answer, but in order to do so we must return to our study of the glacial deposits, for, as we shall find, it is only after a close analysis of their evidence that we can hope to obtain a satisfactory explanation of those apparently contradictory facts which have so exercised the ingenuity of palæontological students.

CHAPTER XII.

INTERGLACIAL EPOCHS.

Earliest recognition of interglacial deposits—Interglacial beds of Scotland—Sections at Hailes Quarry, near Edinburgh—Alternating arctic and genial climatic conditions—Succession of glacial and interglacial deposits in England—Palæolithic implements in interglacial deposits at Brandon, Suffolk—Changes of climate during Glacial Period in British area—Glacial deposits of Scandinavia—Ancient *strand-linier* or horizontal rock-terraces of Norway—Theories of their origin—Their possible interglacial age—Interglacial deposits of Northern Germany—Section at Rixdorf, on the Spree—Section at Dömitz, on the Elbe—Interglacial beds at Tempelhof—Boring near the Schwielow-See—Traces of interglacial submergence—Glacial and interglacial deposits of Saxony; of Holstein and Denmark—Sand, gravel, and superficial erratics of Northern Europe—Dr. Penck's views of climatic and geographical changes—Preservation of beds under till or boulder-clay.

Some five-and-twenty years ago M. Morlot pointed out that after the ancient glaciers of Switzerland had for a long time occupied the low grounds of that country, they retired again to the mountain-valleys, and allowed streams and rivers to erode and re-arrange the ancient bottom-moraines and other *débris* which had been left strewed over the deserted bed of the *mer de glace*. After some considerable period of time, however, the glaciers, according to Morlot, again advanced and overflowed the low grounds, here and there ploughing out the superficial river-alluvia, and elsewhere burying them under a newer accumulation of boulder-clay or *moraine profonde*.[1] The bearing of these interesting observations upon the glacial history of other regions, however, was not recognised for a number of years. Meanwhile, Professor Ramsay had simultaneously worked out the succession of changes which had obtained in North Wales during the Ice Age, and showed that a period of great glaciation had been succeeded by one of submergence, when the sea rose to a height of 1300 feet or thereabout. This very considerable submergence of the land was in turn followed by re-emergence, and by the re-advance of the glaciers, which, grinding down the valleys, swept out the marine deposits that had accumulated in the interval of depression.[1] As it was formerly the general belief that the cold of the Glacial Period in Britain and Northern Europe was induced by a great elevation of the land, geologists naturally assumed that the milder conditions which followed were directly due to the lowering of the land, while the subsequent re-advance of the glaciers was no less reasonably inferred to have been the result of a second considerable elevation. The discovery made some years later that the lignites of Dürnten and other places in Switzerland were intercalated between glacial deposits added very considerable strength to M. Morlot's contention that the Ice Period in Switzerland had been characterised by considerable oscillations of climate. In 1863, my brother, Professor A. Geikie, described a number of sections in various parts of Scotland which showed a similar intercalation of freshwater beds and peat in boulder-clay. He pointed out that these beds having been formed upon a land-surface, indicated that the boulder-clay was not the result of one great catastrophe, as was then generally understood in Britain, "but of slow and silent, yet mighty, forces acting sometimes with long pauses throughout a vast cycle of time."[2] Morlot had suggested that the facts described by him in Switzerland might possibly point to some cosmical cause, and was of opinion that "the idea of general and periodical eras of refrigeration for our planet, connected perhaps with some cosmic agency, may eventually prove correct." But this view received no support, English geologists maintaining with Lyell that all the vicissitudes of climate to which the earth's crust bears witness might quite well result from changes in the distribution of land and sea. The Glacial Period was therefore held to owe its origin to a former wider extent and greater elevation of the land in northern and temperate latitudes, and any indications of oscillations of climate which might appear to present themselves in the phenomena of the glacial deposits were either ignored or thought to be entirely local, and due to some inconsiderable changes in the relative position of land and sea. But the appearance in 1864 of Mr. Croll's remarkable paper "On the Physical Cause of the Change of Climate during Geological Epochs" threw a new light upon the question, and, by increasing the interest of geologists in the study of the Glacial Period, led the way to many subsequent discoveries of interglacial beds, both in this country and abroad. I have elsewhere endeavoured, at considerable length, to show that Croll's theory is the only one which explains the phenomena,[1] and I do not mean to re-discuss the subject here, but shall confine myself to such a statement of facts as may serve to indicate the nature and extent of those climatic changes which took place during the Glacial Period. We shall see that Morlot's suggestion that the facts might point to some cosmical agency must be true, while the views upheld by Lyell and many of his followers entirely fail to account for them.

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[1] *Bull. de la Soc. Vaud. des Sciences Nat.* (1854), t. iv. pp. 39, 41, 53, 185; *Edin. New Phil. Journ.*, vol. ii. (New Series), p. 14.

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[1] *Quart. Journ. Geol. Soc.*, vol. viii. p. 371. See also, by the same author, *The Old Glaciers of Switzerland and North Wales.*

[2] "On the Phenomena of the Glacial Drift of Scotland," *Trans. Glasg. Geol. Soc.*, 1868.

In glancing over the evidence supplied by the interglacial beds of Europe, it will be most convenient to begin with our own islands, Scandinavia, and Germany—that is to say, with those regions which, as we have seen reason to believe, were overwhelmed by the great northern *mer de glace.* I shall then take up the evidence of the Swiss, Italian, and French interglacial deposits, and conclude with some remarks on certain cognate accumulations which appear upon the borders of the Mediterranean.

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[1] *Great Ice Age*, passim.

It will be remembered that Scotland, during the climax of the Ice Age, was smothered in a thick sheet of ice, which coalesced in the east and north-east with the Scandinavian *mer de glace,* while towards the west it occupied what is now the bed of the sea, overflowed the Outer Hebrides, and extended into the Atlantic Ocean for an unknown distance, but probably as far as the present 100-fathom line. The bottom-moraine of this ice-sheet is the well-known till or boulder-clay so abundantly developed, especially in the Lowlands. It is very remarkable that this ancient bottom-moraine contains now and again patches of river- and lake-alluvia, together with beds of peat : and from these have been obtained remains of mammoth, great Irish deer, horse, urus, various insects, sticks of oak, birch, etc., and fragments of other plants, and freshwater entomostraca. In other places, we find in beds between the till, marine shells ; and in certain localities the till itself contains sea-shells scattered through it. If the till be a bottom-moraine, how can we possibly account for the presence of those remarkable intercalated fossiliferous beds? The inferences to be drawn are obvious—the freshwater beds are relics of old land-surfaces—while the intercalated shell-beds represent what was formerly the sea-bottom. But these inferences draw after them certain conclusions, which, however startling they may appear, follow no less surely as a perfectly logical sequence. In the work already referred to, I have described a number of interglacial beds, and pointed out their meaning. From the position occupied by some of the deposits, it can be proved, 1st, That the great ice-sheet melted away from the Lowlands ; 2d, That there supervened a climate capable of nourishing sufficient vegetation to induce mammoths, Irish deer, horses, and great oxen to occupy the country ; 3d, That the climate again became arctic, and another immense *mer de glace* overflowed the Lowlands and buried under a new accumulation of boulder-clay or bottom-moraine such parts of the land-surface as it did not erode. If we reflect for a little, we can hardly fail to be impressed with the magnitude of the climatic changes which are thus indicated. We must first consider the conditions which obtained during the accumulation of the older boulder-clay—a period of intense arctic rigour, when the country was buried in ice to a depth in the Lowlands of 3000 feet or more. Then we have to think of the time required for the gradual change of climate which brought about the dissolution of that enormous mass of ice, and the long lapse of ages involved in the slow advance, first of an arctic and boreal and then of a more temperate flora, before the land was fitted to support the large mammals whose relics have come down to us. Lastly, we have to reflect that these temperate conditions must have continued for some period more or less prolonged before the climate again began to cool down to such an extent that snow and ice eventually resumed their empire, and a *mer de glace*, little less extensive than the first, drowned the mainland, filled up the adjacent seas, and overflowed the islands of the Outer Hebrides.

To illustrate these remarks I may describe a section at Hailes Quarry, two miles west of Edinburgh, to which my attention was called by Dr. Croll. This section was well exposed in 1878 when I visited it, but I have not seen it since. On the 9th July of that year the general succession of the deposits was well shown in one part of the quarry, of which I took the following sketch (Fig. 7). The lower boulder-clay (1) was the usual blue, hard, tough till commonly met with in the district. Above it came an irregular bed of coarse earthy and gritty sand (2), with a few large boulders of dolerite which were most numerous at and near its upper surface. Resting upon this bed was a layer of peat (3), varying from an inch to a foot or eighteen inches in thickness. It contained many fragments of wood—sticks, roots, etc., of what appeared to be principally birch. I detected some wing-cases of small beetles, but unfortunately they had crumbled to dust when I got them home. Mr. Bennie, however, afterwards obtained many more, amongst them being one of *Geotrupes stercorarius*, as determined by Dr. Purves. Above the peat came a bed of pale blue sandy clay from two to four inches (4), which in other parts of the quarry-section was intercalated with the peat; while in some places the peat entirely disappeared, its place being occupied by sand and silt, abundantly charged with vegetable *débris*. Sometimes the bed above the peat thickened out to five or six feet, the lower portions containing many roots and twigs which were wanting in the uppermost part of the deposits. Immediately above these fine-grained deposits were two or three feet of a coarse sandy clay containing many angular and sub-angular stones and boulders (5), and this in turn was covered by a mass of tumultuous till of variable thickness (6), from a few feet up to several yards. To complete my account of these interglacial beds, I give the following section taken from another part of the same quarry (Fig. 8). This section shows a thickness of 60 feet of glacial and interglacial deposits. Here, as in the preceding section, we observe two masses of till, both of them being of the same character. At its upper surface the newer of the boulder-clays was somewhat discoloured, but only for a foot or so. Below this depth it was a tough, dark blue, amorphous till, crammed with sub-angular, blunted, striated, and polished stones and boulders. The lower till (B^1) was underlaid at one place (not shown in the illustration) with coarse shingle and angular *débris* of sandstone and other rocks, the former

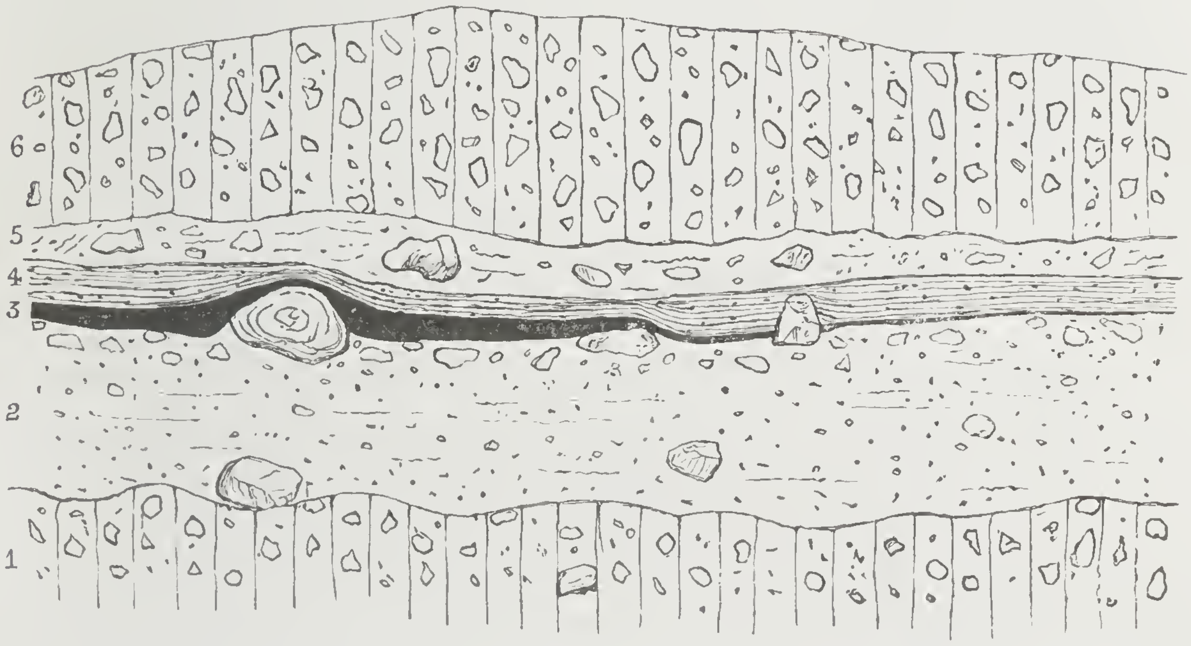

Fig. 7.—Section of Glacial and Interglacial deposits, Hailes Quarry, near Edinburgh.

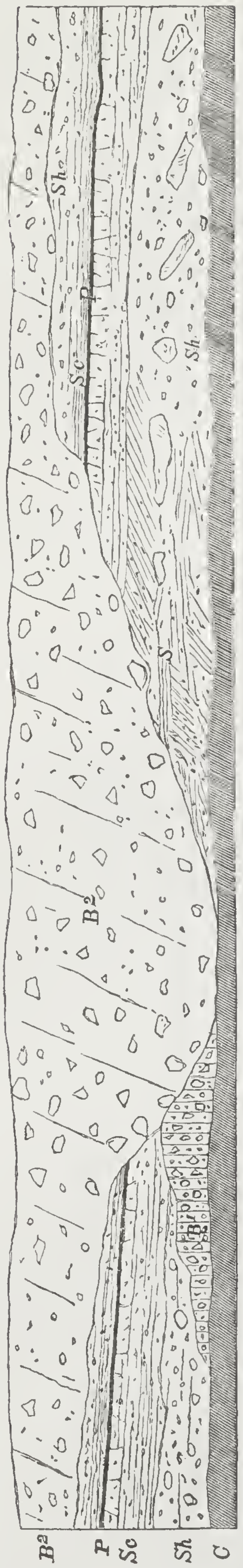

Fig. 8.—Section of Glacial and Interglacial deposits, Hailes Quarry, near Edinburgh.

predominating. Immediately above the till came an irregular bed of similar coarse shingle (*Sh*), which was succeeded by diagonally-bedded sand and gravel (*S*), passing here and there into a very coarse shingle and "alpine diluvium" or confused assemblage of rounded and subangular and angular fragments. Upon the denuded surface of these false-bedded accumulations rested a layer of sandy silt (*Sc*), gray above and passing into yellow below. It varied from two to four feet in thickness, and contained many rootlets. Immediately upon it came a bed of peat (*P*), one inch to eight inches thick, of the same description as that already mentioned. It was covered by gray silty sand or sandy clay (*Sc*), one to two feet, and that in turn by coarse earthy sand and shingle (*Sh*). The overlying till (B^2), it will be observed, cuts down through all the beds, and rests eventually on the lower till and the Carboniferous strata (*C*).

These instructive sections justify us in coming to the following conclusions :—

1st, The lower till is a true bottom-moraine, and could only have been laid down in its present position when Scotland generally was covered with a great ice-sheet. It cannot possibly be due to a mere local glaciation of the low grounds of Midlothian. This is evident from the fact that all the Lowlands lying between the Southern Uplands on the one hand, and the Highlands on the other, must have been covered with ice before the particular neighbourhood in which our sections occur could have been overflowed. It is further made clear by the fact that the lower till contains stones which could only have been derived from the west. This till, therefore, is the bottom-moraine of an ice-sheet which flowed from that quarter, and this eastward motion of the ice in the vale of the Forth, near Edinburgh, was determined, as I have already pointed out, by the mutual pressure of the two ice-sheets which flowed from the Highlands and Southern Uplands respectively. In point of fact, then, the lower till of our sections proves that at the time of its formation all Scotland lay buried in ice. The coarse shingle which underlies it in one place belongs to the lower till; it probably owes its origin to the action of sub-glacial torrents, or it may represent some of the loose shingle which was scattered over the face of the country before the ice-sheet began to overflow that particular district. The beds resting immediately on top of the till are of a somewhat variable character, as will be gathered from the two sketch-sections. In some places they show considerable false-bedding, and consist of well-washed sand and gravel; in other places they are more or less earthy, and abound with angular and sub-angular stones and boulders. They rest upon an eroded or worn surface of the till, and are undoubtedly of aqueous origin; and since they perfectly resemble the deposits which are formed by streams and torrents in the glacier-valleys of Switzerland and Norway, they tell of a time when the ice-sheet melted away, and when the waters derived from dissolving ice and snow washed up and rearranged the old sub-glacial and other morainic materials which the ice-sheet had left scattered over its deserted bed.

2d, The next succeeding deposits bespeak changed conditions. The flood-waters escaping from the retreating ice-sheet had ceased to deluge the low grounds, and in the hollows of the old glacial deposits appeared lakes, into which brooks and streams carried fine silt and sand. By and by the climate had become so far altered for the better that mosses and grasses and birch-trees migrated slowly into the country, and insect-life also made its appearance. The remains in the peat, so far as they have yet been examined, would lead one to infer somewhat temperate climatic conditions. It is true that from this particular bed no bones, horns, or teeth of any mammalia have come, but the presence of large animals in the country is suggested by the occurrence of *Geotrupes stercorarius*, a dung-feeding species. The peat itself appears to consist largely of twigs and branches—a good deal decomposed; and from the presence of rootlets penetrating the underlying sandy silt we may suppose that we have here an old land-surface. From the general appearance of the beds it might be inferred that they mark the margin and bed of a shallow lake, or that they were accumulated in some lake-like expansion of a stream. In Fig. 7 we observe how the underlying "alpine diluvium" has been denuded and washed—the finer materials having been removed and the large stones left behind. We may suppose that the peat which gathers round and over these stones represents the marshy bank of the old lake or stream. Traced in some directions, the peat died out and was succeeded, as I have said, by silt, sand, and clay—deposits evidently contemporaneous with the peat, and indicating either a lake-bottom or the bed of some quiet back-water in a stream. In short, we have here evidence of a land-surface supporting trees, and of streams that carried away vegetable *debris* and insects, and buried them in its silt and sand.

3d, The peaty bed with its overlying silt and clay is succeeded above by coarse earthy sand and gravel, with angular and sub-angular stones and boulders which imply very different conditions. The orderly deposition of fine-grained sediment in quiet water was followed by the action of torrential water, and the accumulation of materials of precisely the same character as those which underlie the old lake-beds. To this tumultuous accumulation succeeds a second mass of tough boulder-clay, whose included stones prove it to have been rolled forward underneath a *mer de glace* flowing in an easterly direction. The phenomena presented by this till lead to precisely the same conclusion as those suggested by the boulder-clay at the base of the section. Once more a great ice-sheet enveloped the country and rolled forward its bottom-moraine. Underneath this second advance of the ice the loose superficial deposits which had formed in the interval were demolished—only a few patches having been here and there preserved. The section Fig. 8 shows how the ancient lacustrine beds have been cut through and the newer till rolled into the gaps and hollows made by the ice-plough.

In other cases we find beds of clay with sea-shells intercalated between a lower and an upper mass of till—the presence of which in like manner compels us to infer that the accumulation of boulder-clay was not continuous but interrupted by one or more long pauses, during one of which a considerable submergence of the land took place.

In England similar evidence is forthcoming. Thus in Lancashire and Cheshire we encounter considerable deposits of sand and gravel, containing sea-shells and other exuviæ of marine organisms, which rest upon and are covered by boulder-clay. In other places, as near Hull, we see estuarine deposits, from which remains of the Pleistocene mammalia have come, occupying a similar position. It is well known, indeed, that there are several distinct beds of boulder-clay visible in the East Anglian districts, which are separated the one from the other by intercalated deposits, some of which are unquestionably of freshwater origin. Mr. S. V. Wood jun. describes a succession of no fewer than four boulder-clays, which, beginning with the oldest, are as follow:—1, The *Cromer clay;* 2, The *Great chalky boulder-clay;* 3, The *Purple clay of Holderness;* 4, The *Hessle clay.*

The oldest of these clays, that of Cromer, rests upon the so-called "forest-bed" of Norfolk, associated with which have been discovered many mammalian remains, including those of elephant, hippopotamus, horse, cave-bear, urus, Irish deer, and many other cervidæ. The fauna is remarkable as showing a commingling of Pliocene and Pleistocene species. Thus we have among the former a bear (*Ursus arvernensis*), a rhinoceros (*R. etruscus*),[1] and a deer (*Cervus polignacus*), which have not yet been met with in any deposits of more recent age. Again, several of the forms which appear in the "forest-bed" are common Pliocene species that seem to have vanished from the European fauna in early Pleistocene times. Among these are, *Machairodus*, and others which occur in the older Pleistocene deposits, but have not been dug up in beds pertaining to the latest stage of the Pleistocene Period. Nevertheless the characteristic Pleistocene fauna is well represented in the "forest-bed" of Norfolk by such animals as cave-bear, wolf, fox, wild-boar, urus, mammoth, Irish deer, roe, stag, beaver, and mole. The fauna of the "forest-bed" is thus intermediate between that of the Pliocene on the one hand and of the Pleistocene on the other, and is more closely allied to the latter than the former.

Here, then, we have evidence to show that the Pleistocene mammalia—those animals with which, as we have seen, Palæolithic man was contemporaneous—were already in occupation of England before the accumulation of the oldest boulder-clay of that country. In those early preglacial times we are confronted with certain animals, some of which seem to have died out with the advent of the first glacial epoch, while a few lingered on, but eventually vanished before the close of the Pleistocene Period, the hippopotamus being the only one of the true Pliocene forms which has survived. Overlying the "forest-bed" comes a series of fluvio-marine beds which have yielded many plant-remains, amongst them being the Arctic willow (*Salix polaris*), and an arctic and high-alpine species of moss (*Hypnum turgescens*). These plants were detected in the upper part of the fluvio-marine series immediately below the Cromer boulder-clay, by Mr. Nathorst. Their evidence is quite in keeping with that supplied by the overlying till. They show that before that till was deposited the climate had become very cold, supporting only a meagre arctic flora. Eventually an extensive ice-sheet overflowed the land, and crept south into Norfolk and probably even into Suffolk.

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[1] According to Professor Brandt, the *R. Merckii*, which occurs in the Pleistocene deposits of Dürnten in Switzerland, is only a variety of the *R. etruscus* of Falconer. See *postea*, p. 299.

The Cromer boulder-clay and its associated deposits of loam, sand, and gravel, with large erratics, are overlaid by certain gravel-beds, which are believed to be the continuation of a series of sand- and gravel-deposits somewhat widely spread over East Anglia. These are usually supposed to be exclusively marine, and they have yielded marine shells which, according to Mr. S. V. Wood, have a preponderating southern facies. Here and there, however, as near Ipswich, they are associated with beds of brick-clay, which seemed to me to be of freshwater origin, and in which fragments of wood, sticks, and logs, have been found. Similar brick-earths occur in the neighbourhood of Brandon, Suffolk, where they have yielded to the researches of Mr. Skertchly implements of characteristic Palæolithic types, along with freshwater-shells and fragments of bones. This is by far the most important discovery of Palæolithic beds which has been made since Boucher de Perthes first detected the flint implements in the ancient river-drifts of Abbeville. And it is more especially gratifying to me as it confirms by direct evidence the views I had been previously led to form as to the interglacial age of many of the implement-bearing deposits of England.

Thus we have evidence to show that after the ice-sheet which laid down the Cromer till had melted away mild conditions of climate ensued. The sea, which then covered some of the low ground of East Anglia, gradually became tenanted with a group of shells which indicate plainly a temperature not lower than that of the seas which now wash the English coast. Moreover, the Brandon freshwater loams and brick-earths show that Palæolithic man had now become a resident in England, and doubtless he would be accompanied by many of the Pleistocene mammals which had been driven south on the approach of the preceding glacial epoch.

Overlying the Brandon beds, with their flint implements, comes the great chalky boulder-clay, or bottom-moraine of an ice-sheet formed during the climax of glacial cold. It is this boulder-clay which has been traced south to the valley of the Thames. Resting upon it occur sands, gravels, and loams of much the same character as those that immediately overlie the Cromer boulder-clay. These deposits are the flood-accumulations formed during the subsequent dissolution of the *mer de glace*, which was brought about by another change of climate. To these deposits succeeds a third boulder-clay, that which is known as the purple clay,—the presence of which points to a third advance of the ice-sheet. Overlying the purple-clay, again, we encounter a series of sands and gravels which in the valley of the Humber have yielded remains of Pleistocene mammalia, together with many shells, conspicuous amongst which, by reason of its abundance, is *Cyrena fluminalis*—a shell which no longer lives in British waters. Lastly, these beds are covered in their turn by a fourth sheet of boulder-clay, the Hessle boulder-clay. Such is the general succession of the drift deposits which are exposed in the sea-cliffs and other sections in Holderness. It proves that these deposits were accumulated under very variable physical and climatic conditions. The great chalky boulder-clay is the *moraine profonde* of the *mer de glace* which flowed south as far as the valley of the Thames. By and by a change of climate ensued, and the ice-front retreated towards the north. To what extent this great covering of ice melted away in Britain before the incoming of the succeeding *mer de glace* which deposited the purple boulder-clay we cannot tell. There are certain patches of shelly clay that occur above the great chalky boulder-clay which lead us to believe that, after the retreat of the ice underneath which that till was formed, the North Sea was tenanted by an arctic fauna. Recently, Mr. Lamplugh has described the occurrence in a till near Bridlington Harbour of patches of freshwater beds, with peat and many shells of a variety of *Lymnæa peregra*, which appear to be intermediate in age between the great chalky boulder-clay and the purple boulder-clay.[1] But whether these freshwater beds be older or younger than the clays with arctic shells cannot be well made out. They tell us, however, that between the accumulation of the two tills referred to, a land-surface existed in Yorkshire, and this of itself implies a very considerable lapse of time, not less than a great change of climate. Plants once more crept north, and molluscs found their way into the streams and pools. Again, however, the climate changed, and another vast ice-sheet overflowed the country, and ploughed out marine and freshwater deposits, which we now find confusedly commingled with the lower part of the purple boulder-clay. This third ice-sheet went south as far at least as Lincolnshire. The beds which succeed to the bottom-moraine of this ice-sheet afford very convincing evidence of a complete change of climate. They have yielded remains of the Pleistocene mammalia and estuarine and marine shells—the general facies of which implies climatic conditions as favourable as those of the present day. Yet once more those glacial conditions vanished, and a fourth and last ice-sheet overwhelmed the land, flowing south into Lincolnshire, but perhaps not extending so far as that of the third glacial epoch.

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[1] *Geological Magazine*, Dec. ii. vol. vi. p. 393.

Thus we have evidence in these English sections of no fewer than four glacial epochs separated by intervening epochs of mild climatic conditions. During the mild interglacial epochs the Pleistocene mammalia made their appearance, and Palæolithic man was likewise an occupant of English soil.

In the north-west of England and in the east of Ireland there occurs a triple series of drift-deposits, as was first clearly indicated by Professor Hull, consisting of a lower and an upper boulder-clay, with an intervening group of marine deposits, which attain in some places a thickness of several hundred feet. These, as I believe, are the equivalents of the upper part of the glacial series as developed upon the Yorkshire coast. The lower boulder-clay of Lancashire and Cheshire and Ireland corresponds to the purple boulder-clay of Yorkshire; the middle sands and gravels of the north-west of England and the northern and central districts of Ireland are represented in Yorkshire by the Hessle estuarine beds; and the upper boulder-clay on both sides of the Irish Sea corresponds to the Hessle boulder-clay of Holderness. Bearing this correlation in mind, let us now attempt to sum up the general physical and climatic changes which obtained in the British area during the last interglacial and concluding glacial epochs.

The dissolution of the *mer de glace* underneath which the purple boulder-clay accumulated was followed by the appearance of a wide land-surface in England. The British area formed at that time a part of the Continent, and the Pleistocene mammalia —horse, mammoth, ox, deer, etc.—invaded the land. Eventually a gradual submergence ensued, and the sea by and by overflowed wide regions. Traces of this ancient submergence have been met with up to a height of over 1200 feet in Ireland, of more than 1300 feet in Wales, and of 500 feet in Scotland. During the earlier stages of that submergence the climate was mild and genial, as is shown by the presence of *Cyrena fluminalis* and other shells in the estuarine beds near Hull. But the temperature of the sea fell as the submergence continued, the general facies of the fossils which occur in the north-west of England and in Ireland indicating upon the whole colder conditions than now obtain in the adjacent waters. This conclusion is borne out by the character of the shells in the high-level Scottish beds which have yielded *Tellina calcarea* and *Cyprina islandica,* the former a shell which does not now live in British seas, but ranges north from the Danish shores of the Baltic to Spitzbergen. It is evident then that during the deposition of the "middle sands" of England and Ireland, the British Islands must have formed an archipelago of islets. Although no marine deposits occur in Scotland above a height of 500 feet, we must not assume, for reasons that will presently appear, that the depression of the land was not so great in that direction. But the submergence appears certainly to have decreased towards the south to about 40 feet in the Fenland, and some 20 to 60 feet or so along the borders of the English Channel. In Cornwall, Devon, Dorset, etc., and at various points on the opposite French coasts, occur deposits of marine gravel and sand, extending from

10 to 20, and in some places exceptionally to 60 feet above the sea, which mark the limits reached by the submergence of the epoch in question. The shells indicate a climate very much like that of the present, but they have upon the whole a somewhat more northern facies. How long our area continued depressed to the extent now indicated can only be conjectured, but time was required for the erosion of beaches, and for the accumulation of the massive beds of sand and gravel that extend over considerable areas in the north-west of England, and in Ireland.

By and by, however, as the climate continued to deteriorate, the land began to re-emerge, and eventually attained a higher level than the present, but how much higher it is impossible to say. Snow now gathered thickly upon the mountains, and glaciers crawled down the valleys and deployed upon the low grounds ; the last glacial epoch had fairly set in. In Scotland the ice-streams became confluent, and the snow, precipitated heavily over all the Lowlands, gradually accumulated to form an ice-sheet hardly less massive than any of those which had gone before. We know from the direction of the rock-striations and the carry of the stones in the youngest boulder-clay of Scotland, that the Scottish and Scandinavian *mers de glace* of this epoch were coalescent. The ice, ploughing over the surface of the country, swept out the more or less loose deposits of freshwater and marine origin, which had formed during the preceding interglacial epoch, and left only a few patches here and there as monuments of what had once been. The ice-stream that crawled down the Moray Firth was forced to overflow Caithness, and in doing so it rolled forward with its bottom-moraine a confused assemblage of shells belonging to different zones, which, during the preceding interglacial epoch, had gathered upon the submerged low grounds and what is now the bed of the Moray Firth. Hence the bottom-moraine of the *mer de glace*, which overwhelmed Caithness, contains many broken, crushed, and striated shells, scattered through its mass in the same manner as the stones and boulders. We meet with the same phenomena in the north of Lewis, where the bottom-moraine of the ice-sheet that crept over that island is abundantly charged with shelly *débris*, derived from the bed of the Minch.

It is the bottom-moraine of this latest great *mer de glace* which appears at the surface all over Scotland and the north of England. In the eastern counties of the latter country it has been followed south as far at least as North Lincolnshire ; in the west it forms, as I have said, the upper boulder-clay of Lancashire and Cheshire, and it is the superficial till of North Wales. It covers also a wide region in the central and north-eastern districts of Ireland. Although much yet remains to be done before the southern limits of this latest ice-sheet are definitely ascertained, yet the evidence is sufficient to enable us to form a rough approximation to the truth. The basin of the Irish Sea was filled to overflowing by ice coming from each of the three kingdoms, while at the same time the Scandinavian *mer de glace* occupied the bed of the North Sea, and pressed back the ice creeping out from Scotland and England. The high grounds of Northern England were deeply buried, but when we come south as far as Derbyshire traces of recent glaciation disappear, and the hills begin to show fewer marks of abrasion. It is probable that, during the latest glacial epoch, the Peak and other hills in that part of England were not overwhelmed by the general *mer de glace*. A broad stream of ice, however, flowed out of the Irish-Sea basin into Cheshire, and was probably coalescent there with ice creeping down from the Welsh mountains. Charnwood Forest appears at the same time to have supported a little ice-sheet of its own, which, flowing out in all directions, carried boulders north, south, east, and west. In the basin of the Irish Sea the ice, being of enormous thickness, probably extended south as far as Wicklow and Pembroke.

In the south of England it is doubtful whether any true glaciers existed at that time, but the angular *débris* which overlies the raised-beaches on both sides of the Channel, and which bespeaks, as Mr. Godwin-Austen long ago pointed out, cold climatic conditions, is in all probability the subaerial equivalent of the latest boulder-clay of Scotland, Ireland, England, and Wales. Of the southern extension of the North Sea *mer de glace* I will speak farther on.

The final dissolution of the latest ice-sheet in Britain was followed as usual by the accumulation of vast quantities of sand and gravel, boulders and angular *débris.* Flooded rivers, torrents, and inundations, spread sand and gravel in wide sheets over the low grounds, which reach to such heights and are distributed over so wide an area that they have sometimes been attributed to the sea, although they have no particular resemblance to marine deposits, and are quite destitute of marine organic remains. It cannot be denied, however, that some of the gravel-deposits are with difficulty to be accounted for by mere flood-action. They occur upon valley-slopes, and are spread over the intervening plateaux between valleys in such a way as to suggest that some other explanation of their origin must be forthcoming, and such an explanation has been furnished by Mr. Darwin (see *supra,* p. 141). Doubtless the phenomena described by him were reproduced more or less extensively with every return of glacial conditions, all through the Ice Age. One can readily understand how, during the latest cold epoch, the floods and torrents would frequently undermine and redistribute alluvial deposits of interglacial age — how they would sweep together all relics lying loose upon the surface, and again scatter these broadcast—so that flint implements and the bones both of arctic and southern mammals might come to be commingled in those pell-mell accumulations of angular gravel which afterwards gradually settled down as the frozen snow with which they had been interbedded melted slowly away.

While such changes were taking place in the low grounds of Southern England, the northern ice-sheet continued to retire towards the heights, strewing hill-slope and valley-bottom with its superficial moraines and erratics. Eventually a time came when it ceased to invade the Lowlands, withdrawing, as it were, to the mountains, where it broke up into a series of local glaciers, and ere long finally vanished. In Scotland the closing scenes of this latest glacial epoch are more fully represented than is the case either in Ireland or England. In neither of the latter during or after the melting of the ice would the sea appear to have gained to any extent upon what is now land ; there are no late glacial shell-beds like those of the Scottish maritime districts.[1] The ice melted off the low grounds of Scotland, and was followed shortly afterwards by the sea, which rose to rather more than 100 feet above its present level. To this partial submergence belong those marine and estuarine deposits of the Clyde, the Forth, and the Tay, which are characterised by the presence of arctic shells, the Arctic seal, and many ice-floated blocks and stones. Farther north the submergence appears to have increased to as much as 200 feet, my colleague, Mr. Horne, having detected late glacial marine beds up to that height above the sea in Morayshire.

Crossing over to Scandinavia, we learn that notwithstanding the severe glaciation which that region has experienced, patches of freshwater interglacial beds have been preserved. These interesting relics, described by Holmström, E. Erdmann, Nathorst, and others, are eloquent of great physical and climatic changes. Hitherto such "finds" have been encountered only in the south of Sweden, and, so far as I know, not a trace of any interglacial epoch has been recognised in Norway. There are certain phenomena, however, connected with the "gamle strandlinier" or old beach-lines of that country which may possibly be connected with interglacial changes. But before referring to these I may first sum up in a few words what is known of the late glacial deposits of Scandinavia. The final dissolution of the ice-sheet was accompanied there, as in Britain, by the distribution of much gravel and sand and morainic *débris*, and by the scattering of large erratics over hill-side and valley-bottom. In many places the old bottom-moraines were much eroded and their materials re-arranged and re-distributed. The melting of the ice was likewise attended or followed by the gradual submergence of the land in Southern Norway to a depth of 640 to 700 feet.[1] From these heights down to the level of the sea, beds of clay, sand, and gravel, charged with the remains of an arctic marine fauna, are met with more or less abundantly. As I shall point out in a subsequent chapter, they are overlaid by a newer set of strata of postglacial age. Now, it is somewhat remarkable that these high-level shelly clays and beach-deposits appear to be restricted to Southern Scandinavia. At all events no trace of them would seem as yet to have been observed in Northern Norway. But, as is well known, many old beach-lines, cut in the living rock, occur plentifully along nearly the whole coast, from Skonevig in the extreme north to Christiania in the south; and some of these beach-lines, if such they be, attain a greater elevation than is reached by any of the glacial shell-beds.[2] Thus Kjerulf and Mohn record heights ranging between 500 and 569 Norwegian feet (=515 to 586 English feet). Nearly all those who have described the "gamle strand-linier" attribute their origin in some way to the sea; they are generally believed, in fact, to mark former sea-levels. There are difficulties, however, in the way which this view does not entirely remove. In the first place, they hardly resemble the beaches which are being now formed in Norway. Indeed, according to S. A. Sexe, no such rock-shelves occur at the present water-level. "I cannot say," he remarks, "that I have seen any such incision there which I could imagine as a future ancient coast-line in case the land should rise in the future, although I have travelled not a little both on our fiords and along the coast facing the open sea." In the second place, the strand-lines in closely adjoining fiords seldom agree either in number or in relative height. Thus Professor Mohn found that the strand-lines in the neighbourhood of Tromsöe could be arranged in six groups, of which the average levels were as follow:—

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[1] With the somewhat trifling exception of the "Nar Valley beds" of East Anglia.

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[1] According to Kjerulf, clays with Arctic shells reach a height of 400 to 460 feet above the sea, while shell-banks of the same age go up to 530 feet. He allows 40 fathoms or so (240 to 250 feet) as the depth at which the high-level clays were accumulated, which, added to 400 to 460 feet, will give us 640 to 700 feet. The shell-banks would require some 90 feet of water for their formation, and this, added to 530 feet, gives 620 feet. In Sweden, according to A. Erdmann, the submergence was greater, but he includes the åsar or drift-ridges amongst the marine deposits, a view which is now generally abandoned by Swedish geologists.

[2] For descriptions of the "gamle strandlinier" of Norway see Keilhau: *Nyt Mag. for Naturvidensk.*, Bd. i. (1837) p. 105; Bravais: *Comptes Rendus de l'Acad. des Sci.*, t. x. (1840) p. 691, and *Voyages de la Commission Scientifique du Nord en Skandinavie, en Laponie*, etc. (1842); R. Chambers: *Ancient Sea Margins* (1848), p. 289, and "Tracings of the North of Europe," *Chambers's Edinburgh Journal*, 1849-1850; Kjerulf: *Universitets-program* (Christiania) *for förste Halvaar*, 1870; *Ibid. for andet Halvaar*, 1872; *Udsigt over det sydlige Norges Geologi*, 1879, p. 17; S. A. Sexe: Paper accompanying *Index Scholarum* of the University (Christiania) for first season, 1872; *Universitets-program* (Christiania) *for förste Semester*, 1874; *Forhandlingar i Videnskabs-Selskabet i Christiania*, 1874, p. 185; *Archiv for Mathem. og Naturvidensk.*, Bd. i. (1876) p. 1; H. Reusch: *Forh. Vidensk.-Selskab.* (Christiania), 1874, p. 284; *Ibid.*, 1878, p. 1; *Nyt Mag. for Naturvidensk.*, Bd. xxii. (1876) p. 169; H. Mohn: *Nyt Mag. for Nat.*, Bd. xxii. (1876) p. 1; K. Pettersen: *Archiv for Mathem. og Naturvid.*, Bd. iii. (1878) p. 182; Bd. iv. (1878) p. 167; *Tromsöe Museums Aarshefter*, Bd. i. (1878) p. 66. An excellent résumé of the present state of our knowledge of the "gamle strandlinier" is given by Dr. Richard Lehmann in the *Programm der Realschule I. Ordnung im Waisenhause zu Halle für das Schuljahr* 1878-1879.

1st	group,	62	feet	above sea.
2d	„	89	„	„
3d	„	124	„	„
4th	„	159	„	„
5th	„	194	„	„
6th	„	258	„	„
7th	„	304·5	„	„

The strand-lines of the first group varied in level between 53 and 72 feet; those of the second between 82 and 90 feet; those of the third between 114 and 132 feet; those of the fourth between 154 and 162 feet; those of the fifth between 190 and 202; those of the sixth were noticed only in two places, and stood at practically one and the same level; and those of the seventh ranged between 301 and 308, but they likewise occurred only at two localities. These differences of level may perhaps be more or less readily accounted for, partly by the configuration of the ground where they occur, which would doubtless have its influence upon the rise and fall of the tide, and partly upon the set of the tidal current itself. Every one knows that even on our own shores the tides attain unequal heights, and the same held good when our maritime regions were partially submerged in postglacial times, as we know from the testimony of the raised-beaches that fringe our coast-lands. It is quite possible also that a more rigid system of measurement than has yet been applied to the "gamle strandlinier" may materially reduce some of the present apparent discrepancies. But how are we to account for the capricious distribution of the strand-lines? In some fiords they are more or less well marked and occur at several successive levels, while in others either one or more of the series may be wanting, or strand-lines may be altogether absent. Helland has suggested an explanation which gets rid of the difficulty so far. He infers that during the period of submergence some of the fiords would continue to be filled with deep glaciers like those of Greenland, and that the sea being thus excluded no strand-lines would be formed in such fiords. But this ingenious suggestion still leaves unaccounted for cases of closely-adjoining fiords in which are found groups of strand-lines that do not correspond either in number or elevation. To explain such anomalies unequal movements of elevation and depression of the land are out of the question, and even if they were permissible, they would not account for the phenomena. The fiords in which the conflicting and contradictory evidence is found lie much too near to allow us to have recourse to this favourite mode of solving such problems. Professor S. A. Sexe has advanced another view which is directly opposed to the theory of the marine origin of the strand-lines. According to him they date back to the Ice Age, and were cut out by the great glaciers that flowed out by the fiords, in which their movement must have been approximately horizontal. And in proof that glacier-ice has had to do with their formation, he points to the occurrence of glacier-carried stones upon a strand-line described by him, and to the yet more remarkable appearance of ice-worn rocks and glacial striæ upon another strand-line (45 feet over the sea-level) in Osterfjord. These striæ, however, did not trend horizontally like the strand-line itself, but dipped down towards the opening of the fiord in the same direction as the general glaciation of the hill-slope. It was only at the lowest level close to the water that a second system of horizontally-disposed striæ was observed. I confess it is difficult to conceive how a glacier could excavate horizontal benches in a hill-side ; but, admitting that it could, surely some of the strand-lines occur in positions opposed to the direction followed by the ice-flow ? I have not visited Norway for many years, and my examination of the old strand-lines was very cursory, but if I remember rightly some which I saw between Tromsöe and Hammerfest ran along the coast-lands that faced the open sea. Those, at all events, described by Mohn as occurring on the west coast of Kvalöe, it is hard to believe could owe their origin to glacial erosion. Again, if such were their origin, we might expect to meet with similar horizontal rock-ledges in all mountain-tracts which have in former times been severely glaciated, as in the Alps, the Pyrenees, and the mountains of our own islands.

Mr. Karl Pettersen has advanced yet another view. In his opinion the rock-ledges have been cut out by the scouring action of floating-ice carried along by tidal currents. To this theory also objections arise. Strong currents would probably flow between the islands just as they do at present, but surely in a quiet fiord—a regular *cul de sac*—such scouring action would not be at all likely to take place. I might refer, for example, to the strand-lines in the Jökulsfjord, which I examined in company with Mr. Whitaker and my brother, and which the latter has suggested might "have been due in large measure to the effects of the freezings and thawings along the old 'ice-foot,' and to the rasping and grating of coast-ice."[1]

I feel that I should not be justified in expressing any positive opinion on a question, for the satisfactory solution of which, perhaps, more exact and exhaustive data are required ; but so far as I am able to follow the evidence it seems to point, first, to the marine origin of the "gamle strandlinier," and, second, to the great probability that frost or floating-ice has had a share in producing some of them at least. But even after admitting so much there still remains for explanation the capricious distribution of the ledges, their presence in one place, their absence from another, where the conditions would seem to be as near as may be alike. Certain observations in Scotland have led me to suggest an explanation of the phenomena, which I throw out here for the consideration of my Norwegian friends. At several places on the Scottish coast, particularly in the neighbourhood of Ballantrae in Ayrshire, I have observed rock-ledges of precisely the same character as those which I saw in the north of Norway. They occur at a greater elevation than is attained by any of the late glacial and postglacial shelly clays, which is suggestive, therefore, of their greater antiquity. But what settles this point is the fact that they have been glaciated at a time subsequent to their excavation—they are distinctly *moutonnées.* In connection with this, I note the fact that I found till with striated stones lying here and there in holes and hollows of the surface, all of which puts it beyond doubt that the rock-terraces in question were overflowed by the ice of the last glacial epoch. I have little doubt, indeed, that they mark old sea-levels which were excavated during the last interglacial epoch, and that they are thus contemporaneous with the "middle sands" of Ireland and the north-west of England. Now it seems not improbable that many of the ancient strand-lines of Norway may belong to this period. The glacial striæ observed upon the strand-line in Osterfjord by Sexe, seem to me to tell the same tale as the *roches moutonnées* and till on the Ayrshire rock-terraces. The glaciation is certainly more recent than the formation of the strand-line. If we might suppose, therefore, that many of the old sea-margins of Norway pertained to the same interglacial epoch as those of Scotland, we should explain in a natural way some of the apparently conflicting phenomena to which reference has been made. The absence of sea-shells, etc., and of sand and gravel, or shingle, upon the rock-ledges, would no longer offer a difficulty, for all such loose material would tend to be swept away by the ice. To the unequal erosive action of the glaciers might likewise be attributed the capricious manner in which the ledges appear now to be distributed. Thus in some places they might be partially or entirely effaced, while in others they would escape with only some inconsiderable abrasion. I do not conceal from myself that there are still difficulties which this suggestion may not help to remove. Thus it might be objected that the shelly deposits of Southern Scandinavia have not been demolished. These beds, however, are believed by all who have studied them both in Norway and Sweden, to belong without doubt to a period subsequent to the last great extension of the *mer de glace*,—there has been no general glaciation of Scandinavia since these beds were accumulated. Are we to believe then that the submergence which carried Southern Scandinavia in late glacial times down to a depth of 500 to 600 feet, was not prolonged into the north of Norway? That is by no means improbable. On the other hand, we might possibly explain the absence of high-level shell-beds in Northern Norway, by supposing, with my friend Mr. Helland, that the great fiords were up to a late period still filled with large glaciers like the ice-choked fiords of Greenland. We should thus have two periods of submergence for Scandinavia—the first during the last interglacial epoch, when Wales and Ireland were drowned to a depth of more than 1000 feet, and when Scotland also was deeply submerged; and the second in late glacial times, when the ice was melting away, and a highly arctic fauna lived over the submerged parts of southern Norway and Sweden,—a stage corresponding to that of the late glacial marine and estuarine beds of Scotland.

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[1] *Proc. Royal Soc. Edin.*, 1866, p. 548.

The great Erratic formation of Northern Germany has yielded notable examples of interglacial deposits, the true character of which, however, has only recently been recognised. As I have indicated in a previous chapter, the drift accumulations generally are supposed by many geologists to have gathered upon the sea-bottom at a time when all the low grounds of Denmark, Holland, Northern Germany, Poland,

and a wide region in Middle Russia, were submerged, and icebergs laden with the *débris* of Scandinavian rocks sailed over the drowned countries. The occurrence of marine shells here and there in the boulder-clay of Prussia seemed to afford strong confirmation of this view. But, on the other hand, the discovery of land- and freshwater-shells under similar circumstances appeared directly to contradict the evidence furnished by the presence of the marine mollusca. And the evidence was still farther complicated by the appearance of marine- and freshwater-shells commingled in one and the same section of boulder-clay. Thus in the boulder-clay near Berlin we find such sea-shells as *Mactra solida,* along with freshwater forms, as *Valvata piscinalis.* The freshwater-shells abounded here, and with them were associated remains of the Pleistocene mammalia. In other places solitary specimens of sea-shells (as *Cardium edule* and *Buccinum undatum*) have now and again been detected ; and the same is the case with the freshwater forms *Valvata piscinalis* and *Paludina diluviana.*[1] It is little wonder that this curious commingling of marine and terrestrial relics in the till should have greatly puzzled geologists. Berendt, thinking more especially of the marine fossils, has speculated about the former existence of a wide-spread "diluvial" sea; while others, overlooking or not knowing of the occurrence of the marine forms, have supposed that the drift-deposits were accumulated in a great freshwater lake. Jentzsch, again, was of opinion that the phenomena would be better explained if we could suppose that a large lake formerly occurred in close proximity to a sea ; and Kunth improved upon this suggestion by inferring that there might have been many inland lakes which by and by would become filled with sea-water as the submergence of the land increased. Lastly, Roth put forward the view that the freshwater molluscs may have lived in inlets and shallow bays of the sea which were freshened by the influx of water (streams and rivers) from the land.

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[1] References to the various authorities for these statements will be found in Dr. Penck's paper on the erratic formation of North Germany, *Zeitschr. deutschen geol. Ges.*, 1879, pp. 125, 141.

It is to be noted that most of the shells that occur in the German till are, according to Penck, so broken and abraded that the species is often difficult to determine ; and Berendt has figured a specimen of *Cardium edule* which is distinctly striated. Penck found a similar specimen in the boulder-clay of Marienburg in West Prussia, and the geological collection in the University of Breslau, he says, contains another. The same geologist mentions another noteworthy fact ; the shells are sometimes filled with a material differing entirely from that of the till in which they lie embedded. Thus a specimen of *Paludina diluviana* in the coarse boulder-clay of Rixdorf, which lies a few miles east of Berlin, was filled with a fine ductile clay, and a *Nassa reticulata* from the boulder-clay of Dirshau in West Prussia, with fine sea-sand. It is evident, indeed, that all these sporadic specimens of molluscs are merely erratics like the glaciated stones amongst which they occur. They have been derived from some pre-existing beds which the *mer de glace* has demolished and commingled with its bottom-moraine. The question now arises whether we can tell anything about the history of those beds which have thus been so highly broken up and destroyed. Were they of preglacial or interglacial age ? Fortunately some portions have been preserved, the position of which, intercalated between two distinct sheets of boulder-clay, settles at once their interglacial age.

On the valley-slopes of the Spree, in the neighbourhood of Rixdorf, there is a line of sandpits in which the following section is laid bare :—

1.	Upper boulder clay . . .	6 to 10 feet.
2.	Sand, with gravel and rolled stones in under portion	30 „ 40 „
3.	Lower boulder clay . . .	10 „
4.	Sand.	

From the sand (No. 2) many remains of the Pleistocene mammalia have been disinterred. The species are *Elephas primigenius, E. antiquus, Rhinoceros tichorhinus, R. leptorhinus, Bos priscus, Cervus megaceros.* Freshwater-shells accompanied these remains.[1] Out of a bed of sand at Kreuzberg, occupying a similar interglacial position, remains of the musk-sheep (*Ovibos moschatus*) have been obtained.[2] Thus, we have clear evidence that the Glacial Period in North Germany, like that of Scandinavia and our own islands, was not a long uninterrupted period of severe arctic cold. The ice which had at one time overflowed the great plains down to the high grounds of Saxony melted away, and the Pleistocene mammalia occupied the area from which, doubtless, they had been driven before the advance of the snow and ice. It is highly probable that the Rixdorf interglacial beds belong to the last interglacial epoch, and to the same era we should probably assign the interglacial infusoria-beds near Dömitz (Mecklenburg-Schwerin) on the Elbe. Professor F. E. Geinitz has described[3] a section exposed in the brickworks at Wendisch-Wehningen, which shows the following succession:—

1. Thick overlying mass of boulder-clay.
2. Layer of finely-laminated clay; a few inches thick.
3. Band of black infusoria-earth; eighteen inches.
4. Layer of finely-laminated clay; a few inches.
5. Yellow boulder-clay of variable thickness.
6. Fine sand.

The black-earth is rich in humus, and abundantly charged with freshwater diatoms, which are also plentifully present in the thin layers of clay between which the "infusoria-earth" occurs. The freshwater beds are bent and distorted, and thus partake of the disturbances which are a common feature of the drift deposits throughout all Mecklenburg.

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[1] Beyrich: *Zeitschr. deutsch. geol. Ges.*, 1868, p. 647; Dames: *Ibid.*, 1875, p. 481. Professor Berendt showed to Mr. Helland a reindeer's horn, which, he said, had come from the same place. *Zeitschr. deutsch. geol. Ges.*, 1879, p. 92.

[2] Roemer: *Zeitschr. deutsch. geol. Ges.*, 1874, p. 601.

[3] *Beitrag zur Geologie Mecklenburgs*, 1880, p. 40.

On the same geological horizon as the ossiferous sands of Rixdorf occur the freshwater sands of Tempelhof (Mark Brandenburg), which have yielded *Paludina diluviana*, Kth., *Bithynia tentaculata*, L., *Valvata piscinalis*, Müll., and *Pisidium amnicum*, Müll.

It was formerly supposed that only two boulder-clays occurred in North Germany, which were ranged, along with associated beds of clay, sand, and gravel, in two groups, termed respectively Upper and Lower Diluvium; but it is now known that the lower boulder-clay which appears under the ossiferous beds of Rixdorf and the freshwater shelly deposits of Tempelhof is not the oldest till. In the neighbourhood of Potsdam it is underlaid by an older set of freshwater deposits, which contain the same species of shells as those at Tempelhof, with the addition of *Succinca amphibia*, while immediately underneath these beds comes a third boulder-clay. That this last boulder-clay may possibly represent the ground-moraine of more than one ice-sheet is shown by a boring made near the Schwielow-See, which, according to Berendt, gave the following results:—

	Mètres.		Mètres.	
Boulder-clay	2·6	Boulder-clay	3·3.	A.
Stoneless clay	0·6			
Boulder-clay	0·1			
Sand	1·0	Sand, etc.	2·5.	B.
Boulders	0·8			
Gravel	0·7			
Boulder-clay	0·5	Boulder-clay	6·5.	C.
Sand	0·5			
Boulder-clay	0·5			
Sand	2·0			
Boulder-clay	3·0			
Sand	1·0	Sand, etc.	7·3.	D.
Gravel	1·6			
Gravel and boulders	2·4			
Boulders and gravel	2·3			
Boulder-clay	0·2			E.

It is quite possible that the sand-beds B and D may represent interglacial beds; on the other hand they may be merely lenticular masses belonging to the boulder-clay itself, due perhaps to the action of subglacial waters. Be this as it may, we have in the evidence given above clear proof, as Dr. Penck has admirably shown, of the existence of at least three boulder-clays, separated the one from the other by intercalated deposits of freshwater origin.

But if we have evidence of the existence of a land-surface in North Germany during interglacial times, we have no less certain proof that the same land-surface has also been submerged. Between the upper and lower clays of the province of Prussia come beds of sand and gravel, which, according to Berendt, have yielded a number of shells of marine molluscs, such as *Cardium edule, Nassa reticulata, Cyprina islandica, Mactra solida;* and from the same beds Jentzsch has recorded *Yoldia* (*Leda*) *arctica*, and the fresh- or brackish-water form *Paludina diluviana.* This commingling of discordant species, and the fact that the specimens of *Yoldia* are all much rolled and worn, have led some to doubt whether they really occupy their original bedding-place. But Jentzsch points out that they are widely distributed through the beds in which they occur, and thinks there can be no doubt that they are in place and have not been derived from any preexisting strata. In these beds we have, according to Penck, a marine littoral accumulation; they mark the shores of an interglacial sea upon which the shells were cast up and rolled about by the waves, and the few freshwater forms that make their appearance have been washed down, he thinks, by streams and freshets from the land. The lower blue boulder-clay of the same province, which is very abundantly charged with well-scratched boulders, has yielded at Elbing sporadic shells and fragments of *Dreissena* sp. and *Yoldia arctica,* and it is underlaid in the neighbourhood of the Frisches Haff by a bed of fine stoneless clay, which attains a thickness of nearly 200 feet. *Yoldia arctica* occurs throughout this clay sparsely, in strings or thin lines. The specimens are thick-shelled like those in the Norwegian glacial clays, and they are well preserved, some of them having still their epidermis. Besides these, *Cardium edule* also occurs, together with many more or less comminuted fragments, some of which appear to belong to *Cyprina islandica*. Entire specimens of these shells have not yet been found, all, with the exception only of *Yoldia*, being crushed and broken. That the clay in which they occur has experienced enormous pressure is shown, says Penck, by the extraordinary confusion and disturbance of its bedding. In fact it has been so firmly compressed and squeezed, and is now so hard that at the tileries they blast it with gunpowder.

Freshwater beds of sand with *Dreissena* sp. and *Valvata* sp. were detected by Penck in association with this *Yoldia* clay. They were characterised by the presence of small fragments of northern rocks, such as bits of Silurian from Gottland, and fragments of felspathic and crystalline rocks. These he thinks could only have been derived from some pre-existing mass of boulder-clay in Germany—probably on the same horizon as that of the third or lowest boulder-clay of Mark Brandenburg.

Passing south into Saxony we find that the upper boulder-clay of Prussia and North Germany is wanting, the two boulder-clays which do occur corresponding to the second and third boulder-clays of Mark Brandenburg. The succession of deposits given by Penck is as follows :

Drift-Formation of Saxony.

1. *Upper boulder-clay*, containing isolated sporadic specimens of *Paludina diluviana*. This bed corresponds to the second boulder-clay of Mark Brandenburg.
2. *Flood- and River-gravel and sand.*—On same horizon as the freshwater interglacial beds of Potsdam, and the marine stoneless clay of Elbing, near the Frisches Haff.
3. *Lower boulder-clay*, representing the third or lowest boulder-clay of Mark Brandenburg.
4. *Sand with northern materials* . . . Corresponding to the sand and northern materials which underlie the lowest boulder-clay of Mark Brandenburg.

One of the most interesting points in connection with the drift-deposits of Saxony is the commingling, in certain of the beds, of stones which have come partly from the north and partly from the south. This curious fact has been noticed by many observers—by Cotta, Beyrich, Girard, Lasard, Orth, Credner, Dathe, Penck, and Jentzsch. The Leipzig gravels, in which chalk-flints derived from the north are common, are yet full of stones which could only have come from the hilly districts to the south ; and according to Dathe, south materials predominate in the district between Döbeln and Dahlen close to the Prusso-Saxon boundary. Southern stones also appear still farther east, at Grossenhain, and in the country north of Dresden, between Radeberg and Kamenz. In this latter district the majority of the stones are local or from the north, but among these an occasional truant from the south may be detected. Such stones of southern origin are restricted as a rule to the gravels (No. 2 of the preceding table) ; but now and again specimens are found in boulder-clay. The origin of these phenomena is thus explained by Penck. The lower sand with northern materials pertains to the first glacial epoch at the climax of which the northern *mer de glace* approached the base of the Harz and Erz mountains, and covered Saxony with a sheet of boulder-clay. Then came a change of climate when the ice-sheet melted away, and when rivers and streams flowing north from the Saxon highlands denuded and re-arranged the lower boulder-clay, and commingled its stones and boulders with gravel and shingle derived from the south. This was the first interglacial epoch. After some time a second glacial epoch ensued, when a northern ice-sheet again advanced into Saxony, and rolled its bottom-moraine over the country. The interglacial gravels were then ploughed out in many places, and their materials thus became incorporated in the second boulder-clay.

The drift-deposits of Holstein and Denmark, like those of Germany, are divided into Upper and Lower Diluvium. Each of those countries contains an upper and a lower boulder-clay, separated by intervening deposits of gravel, sand, and clay. At Fahrenkrog in Holstein a clay between the upper and lower boulder-clay has yielded *Mytilus edulis, Tellina balthica, Mactra subtruncata, Mya* (fragments), *Littorina, Littorinella, Chenopus* (*Aporrhaïs*) *pes-pelicani, Bulla, Balanus, Valvata, Cythere lutea.* The presence of the freshwater *Valvata* clearly indicates the proximity of some land-surface from which it was washed down. In connection with this it is worth noting that Möbius has chronicled the discovery of an atlas of *Bos primigenius* in the upper boulder-clay at Ellerbeck.[1] Underneath the lower boulder-clay occur well-bedded clays (*Bänderthone*) containing only a few sporadic stones, most of them angular and consisting of red felspar, granite, and gneiss. These stones, according to Penck, have probably been derived from the wreck of a still older boulder-clay, on the same horizon as the third boulder-clay of Mark Brandenburg. It is remarkable, he says, that the beds underlying the second boulder-clay should yield similar evidence over so wide a region. The *Bänderthone* of Danzig, Pomerania, Berlin, and Holstein, all contain fragments of northern rocks, and some of the clays at least are of freshwater origin. He therefore would assign their formation to an interglacial epoch following after the dissolution of the first ice-sheet, when the ancient bottom-moraine was highly denuded, and its materials re-arranged and re-distributed, gathering here and there in lakes, and also perhaps in the sea.

According to Forchhammer[2] there are no fewer than four boulder-clays in Denmark, separated by intercalated beds of sand and clay; and Puggaard has shown that there are three tills displayed in Möen. From beds between the two lower boulder-clays of that island the last-named geologist obtained *Tellina balthica, Venus ovata, Cyprina islandica, Cardium edule,* and *Turritella* sp. As I have already stated, it was Puggaard's opinion that the great confusion visible in the sea-cliffs at Möens Klint was caused by subterranean movements, but that it is due to the grinding and crushing action of the last ice-sheet, as Johnstrup maintains, appears to be clearly made out. The succession of changes evinced by the drift-deposits of Möen, as given by Dr. Penck, is extremely interesting. After the ice of the first glacial epoch had melted away, the Cretaceous strata of Möen lay undisturbed, and covered with a sheet of boulder-clay. At this time a shallow sea overspread this part of Denmark, and sand with molluscan remains gradually gathered over the surface of the old bottom-moraine. Then ensued the second glacial epoch, when glaciers began to descend to the Baltic, the bottom of which became cloaked with the fine mud carried down by sub-glacial waters. Thereafter the ice gradually advanced, rolling up this mud with its bottom-moraine, and overflowing the Danish country as before. The Cretaceous deposits of Möen being thickly covered by older drifts, were to some extent protected from the grind of this second ice-sheet, as is shown by the fact that the second boulder-clay contains no chalk fragments until we pass westwards of Möen. After the disappearance of this second ice-sheet Möen and the rest of Denmark appeared as a low flat land, which in the course of time was deeply incised by streams and rivers, and eroded by the waves and breakers until it came to present lofty cliffs to the sea, like those which are now to be seen at Stevens Klint. When the ice of the last glacial epoch next advanced upon Denmark, its passage was thus opposed by long precipitous walls of chalk, against which it pressed with enormous force, rupturing and smashing the rock, dragging huge masses of it out of place, squeezing tongues of boulder-clay into the fissures; and in short producing all the wild confusion and disturbance which is now so conspicuous a feature at Möens Klint.

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[1] *Schriften des naturwissenschaftlichen Vereins für Schleswig-Holstein,* 1878.

[2] *Oversigt over det Kgl. Danske Vidensk.-Selskabs Forh.,* 1843, p. 103; *Bull. Soc. Géol. France,* 1847, p. 1178.

The drift-deposits of Faxöe offer a similar succession of boulder-clays, and, like those of Möen, betoken three glacial epochs separated by interglacial eras of milder climatic conditions; and precisely the same results have been obtained by a study of the glacial phenomena in Southern Sweden.

The youngest of all the glacial deposits are those enormous erratic blocks and boulders, and wide-spread sheets, hummocks, and ridges of gravel and sand which appear almost everywhere over the low grounds of Northern Europe. They belong to the time when the ice-sheet was melting away. The erratics were doubtless transported upon the back of the *mer de glace*, and carried southward to its terminal front. They are found covered by, embedded in, or perched upon, the surface of diluvial and morainic sand and gravel. Sometimes they rest directly upon boulder-clay, or, when that is absent, upon some of the older rocks. I have described the mode in which the löss appears to have been formed. Its deposition doubtless continued so long as muddy water overflowed the low grounds of Europe, and hence it belongs to all stages of the Glacial Period ; and its enormous development in Southern Russia, as compared with its sparser appearance upon the plains of Northern Germany, I have already endeavoured to account for. The great accumulations of "Decksand" and "Geschiebesand," which cover such broad areas in Germany, Denmark, Southern Sweden, and Russia, are due partly to the action of diluvial waters derived from melting snow and ice which swept across the low grounds as these were vacated by the *mer de glace.* But much of the materials may have been derived from the surface of the *mer de glace,* upon which it is most probable that considerable quantities of water-worn morainic detritus would tend to accumulate, and to be shot over the terminal front of the ice-sheet.

From this short review of the evidence we gather that the Glacial Period of Germany and Denmark was characterised by several great changes of climate. Dr. Penck has shown us that there are at least three boulder-clays, and there may be more, lying deeply buried under the drift accumulations of Middle Germany. English geologists are especially fortunate in having the secrets of their glacial formations laid bare in magnificent sea-coast sections. Their brethren in Middle Germany, where the drifts probably attain their greatest thickness, must be content with what is revealed to view in river-banks and artificial exposures. The succession made out by them, however, is sufficiently remarkable, and the general results obtained may be thus briefly summed up :—

1. *Lowest Boulder-clay and associated sand and gravel.*—These are the accumulations of the first recognised glacial epoch, during the climax of which the *mer de glace* advanced to the foot of the Saxon uplands.

2. *Sand and gravel with freshwater shells, and clay with marine shells.*—The first ice-sheet had disappeared from Germany and Denmark when these deposits were laid down. They show us that a wide land-surface existed in Northern Germany, the shores of which probably extended to the neighbourhood of the Baltic in Prussia, where we find occasional freshwater-shells in marine littoral deposits. Denmark at this time was under water.

3. *Middle Boulder-clay.*—This indicates the readvance of the ice-sheet in the second glacial epoch. Again it extended as far south as Saxony.

4. *Ossiferous and shelly sands of Rixdorf and Tempelhof, and marine beds of North Prussia.*—Again the *mer de glace* had vanished, and a wide expanse of land appeared in Germany, over which the Pleistocene mammalia wandered. The presence of *Elephas antiquus* and *Rhinoceros leptorhinus*, together with the musk-sheep and the reindeer, betokens change of climate. The two pachyderms must have lived in Germany when the climate of the interglacial epoch had become mild and genial, and the latter when it was colder. The musk-sheep and its congener might thus have entered the country either during the disappearance of the second *mer de glace*, or shortly before the advent of the last. The sand of Gerdauen, with its sea-shells of arctic type, which occurs upon this geological horizon, shows us that towards the close of the second interglacial epoch a somewhat cold sea overflowed the low-lying regions of North Prussia.

5. *Upper Boulder-clay.*—For the last time the great Scandinavian *mer de glace* occupied the basin of the Baltic, overflowed Denmark and Holstein, and advanced as far south at least as Berlin.

6. *Sand, gravel, erratics, etc.*—The melting of the last ice-sheet resulted in the wide distribution of erratic blocks, and the heaping-up of sand and gravel hills, which cover enormous areas in all the low grounds of Northern Germany, Poland, etc.

It may have occurred to the reader who has followed me so far that the phenomena which have been attributed to the action of this great *mer de glace* appear to be contradictory. How, some one may ask, can we believe that the ice which tumbled up the enormous chalk-masses of Möen could at the same time overflow more or less incoherent deposits of sand and gravel like those at Rixdorf without sweeping them entirely away? To which it may be replied, For the same reason that we believe flowing water does in some places erode and excavate, while in other places it accumulates the detritus that results from its own denuding action. One may surely hold that a certain deep ravine or glen, in the upper part of a river-valley, has been excavated in the course of ages by the stream one sees at the bottom, and at the same time assert, without the fear of being considered self-contradictory, that the broad alluvia (overlying, it may be, incoherent marine strata), in the lower and more open reaches of the valley, have been deposited by the very same river that dug out the deep ravine above. What we maintain is simply this: first, that, in regions where the erosive action of the ice-sheet was great, little or no boulder-clay was allowed to gather, and hollows of smaller or larger dimensions were scooped out, when the nature of the ground was favourable to that end; and secondly, that, in places where the grinding-power exerted was less, thick boulder-clay frequently accumulated, and sub-glacial and interglacial beds were often preserved.

The ice-sheet flowed, we cannot doubt, with a differential motion: it must have moved faster in some places than in others. In steep valleys and over a hilly country its course would often be comparatively rapid, but very irregular—lagging here, flowing quickly there—while in wide, open valleys that sloped gently to the sea, such for example as those of the Forth and the Tweed in Scotland, the whole body of the ice would flow with a slower and more equable motion. As the ice-sheet approached its termination, more especially if that chanced to be upon a broad and comparatively flat region, like East Anglia or the plains of Northern Germany, the erosive power of the ice would become weaker and weaker for two reasons: first, because of its gradual attenuation, and secondly, because of its constantly diminishing motion. These, in a few words, are the varying effects which one might *à priori* infer would be most likely to accompany the action of a great ice-sheet. And an examination of the glacial phenomena of this and other countries shows that the actual results are just as we might have anticipated, had it been previously revealed to us that a large part of our hemisphere was, at a comparatively recent date, almost entirely smothered in ice. In places where, from the nature of the ground, we should look for traces of great glacial erosion, we find rock-basins now occupied by lakes; in broken hilly tracts, where the ice-flow must have been comparatively rapid but irregular, and the glaciation severe, we meet with *roches moutonnées* in abundance, but with very little boulder-clay; in regions where the ice-flow has been opposed by cliffs and escarpments, and where, therefore, the lateral pressure would be enormous, the projecting rocks are either bevelled off and highly abraded, or very much crushed, broken, confused, and displaced, and their ruins commingled with the boulder-clay; in open lowlands and in broad valleys where the ice-sheet would advance with diminished but more equable motion, we come upon widespread and often deep glacial deposits, and now and again with interglacial beds; while over regions where the ice-sheet, gradually diminishing in thickness, crawled slowly to its termination, we discover considerable accumulations of boulder-clay, often resting upon apparently undisturbed beds of gravel, sand, and clay.

The distribution of interglacial deposits, therefore, is really in itself a proof that they have been overridden by ice. When they occur in highly glaciated regions, it is only as mere patches, which, occupying sheltered places, have been preserved from utter destruction. In the opener low grounds they are found in greater force, although in such places they almost invariably afford more or less strong evidence of having been subjected to much erosion and crumpling. But the farther we recede from the principal centres of glaciation, and the nearer we approach the extreme limits reached by the ice-sheets, the more extensive and the less disturbed do interglacial deposits become. In a word, they occur in best preservation where the erosive power of the ice was weakest; they are entirely wanting where we have every reason to believe that the grinding force was strongest.

If we look at the interglacial beds themselves with any attention, it is very rarely indeed that we shall not find proof of their having been subjected to more or less crushing and erosion. The overlying till or boulder-clay cuts into them again and again—they are often caught up and involved with the till—and crumpling and contortion are frequently conspicuous. No one who has paid much attention to glacial matters will doubt that all this powerful erosion and confusion is due to the passage of ice over the beds. It may be taken as proved, therefore, that an ice-sheet does under certain conditions ride over incoherent deposits of gravel, sand, silt, clay, and peat, without entirely obliterating them. But all interglacial beds, even in highly-glaciated Scotland, are not equally crumpled and contorted. Occasionally the layers of sand and laminated clay lie quite horizontal, even when the till cuts down, as it were, to the depth of 20 feet and more into the stratified deposits. We have, therefore, further proof that ice may roll its bottom-moraine over incoherent deposits without disturbing the horizontality of their bedding, although at the same time these same deposits may here and there be abruptly cut out and truncated.

If such has taken place in the valleys of a well-glaciated country like Scotland, it surely cannot be unreasonable to infer that in a less ice-worn country, in a region where the ice was not so thick, and where its motion was slower, interglacial beds should be much better preserved. If the ice has spared, in hilly

Scotland, interglacial deposits that range in thickness from a foot or two up to twenty yards and more, where is the improbability of its having overridden much thicker and more continuous deposits in those low-lying parts of England and the Continent where it approached its termination?

And here I may remind geologists of one among many equally suggestive facts, connected with the distribution of interglacial beds in Scotland, that while we have indubitable evidence of submergence of the land, during the last interglacial period, to an extent of upwards of 500 feet, the marine deposits of that date have yet been all but entirely swept away from the higher levels and more exposed parts of the country—there being only one place where they are met with so high up as 500 feet. It is not until we get down to the low country—to the wide open valleys, and to the borders of some of the great firths (which are merely submerged valleys)—that we find the relics of the marine stage of the last interglacial epoch attaining any extent. A good example of this peculiar distribution of interglacial marine deposits came before me recently in the Outer Hebrides. Interglacial beds are met with in two places in the Long Island, namely at Ness and in the Eye Peninsula. The highest point attained by these deposits is about 200 feet above the sea. They rest upon an eroded surface of till, and are themselves overlaid by a second or upper till, underneath which they show a most irregular surface, as a rule, being cut into by the till and crumpled, contorted, and confused. In other parts of the same cliff-section, however, they show little or no disturbance at all, but the till rests upon them apparently quite conformably. In the Eye Peninsula they occur as a mere local patch, which exhibits all the appearance of having been scooped and ploughed out—the clay being abruptly truncated, and overlaid by red till. When these interglacial beds were accumulated, all the low grounds of Lewis, up to a height of 200 feet at least, must have been submerged—and this submergence could hardly have been local and confined to Lewis, but extended in all probability to the whole Outer Hebrides. Where, then, we may well ask, are the marine deposits which must at one time have cloaked these low grounds—where are the clay-beds and sandy deposits and beach-accumulations which must have been laid down contemporaneously with the interglacial beds at Ness and Garrabost? The low grounds in question are sprinkled solely with till, and dotted with morainic rubbish and erratics. Instead of marine deposits, we see only the marks of a recent and severe glaciation. Every vestige of the last interglacial occupation by the sea (with the two exceptions mentioned) has been swept away by the ice-sheet, whose bottom-moraine was rolled over the shell-beds at Ness and Garrabost. And the principal mass of these deposits occurs in the very position where, as I have pointed out more particularly in another place, the ice-sheet must necessarily have exerted less grinding power.[1]

The distribution of the boulder-clay and interglacial accumulations of the Continent furnishes us with abundant evidence of the same kind. It is not, for example, in the mountain-regions of Scandinavia that we meet with great sheets of boulder-clay and intercalated deposits of interglacial age. If our attention were confined to the mountain-valleys we should probably never discover that there had been more than one glacial epoch—the ice of the latest cold period having, as a rule, swept away every recognisable vestige of the beds pertaining to the cold and mild epochs that preceded it. But when we advance southwards into Scania and Denmark—the drift accumulations become thicker—underneath the youngest till many fragments of earlier glacial and interglacial deposits are preserved. And this holds true, likewise, as we have seen, with the drift accumulations of Northern Germany. These are known to attain a great depth, for they represent the bottom-moraines of several successive glacial epochs, together with the marine and freshwater beds which were formed during mild interglacial eras. The latter, however, frequently testify to the enormous weight of the ice which overflowed them—they are compressed and often violently puckered, twisted, and thrown into inextricable confusion—appearances which are well shown in many places, as, for instance, in the neighbourhood of Elbing in Prussia, near Dömitz in Mecklenburg-Schwerin, and again and again in Mark Brandenburg.

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[1] *Quart. Journ. Geol. Soc.*, vol. xxxiv. p. 862.

I have drawn attention elsewhere[1] to certain remarkable facts connected with the distribution of interglacial beds in North America, and have pointed out that the researches of our fellow-labourers in the States and Canada have proved that American interglacial deposits occur in the same peculiar manner as our own:—they are absent or very rarely met with in the regions north of the great lakes, and they increase in importance as they are followed south. Mr. G. Jennings Hinde has recently described some very interesting and important sections, which are exposed upon the shores of Lake Ontario.[2] These sections show no fewer than three separate beds of till with intervening stratified deposits, the lower one of which has yielded many plant-remains and freshwater organisms. The section extends continuously along the shores of the lake for a distance of nine miles and a half, and the fossiliferous interglacial beds attain a thickness of 140 feet. Occasionally they are violently contorted and confused, and in one place the overlying till cuts down into them to a depth of more than 100 feet, the breach occupied by the till being about 450 yards in breadth. Yet throughout the greater part of the section this overlying till rests apparently quite conformably upon the stratified deposits, which then show perfectly horizontal and undisturbed bedding. Here, then, we have a case where one and the same ice-sheet has ploughed out incoherent strata, driving a deep and broad trench through them, although here and there it has allowed them to escape with only severe crumpling, contortion, and confusion, while in yet other places it seems to have rolled its bottom-moraine quietly over their surface in such a way as to leave the beds apparently undenuded and undisturbed.

The same geologist writes me that "up to the present time these interglacial clays, etc., appear to occur only in the lake-depressions and other localities at low levels. I cannot find them in the more elevated district, and supposing a fresh glacier now to creep over this country, it would sweep before and beneath it the till on the uplands, and cover over the stratified clays in the present lakes with this material ; and there would thus be a repetition of the same arrangement of stratified beds and overlying till as is now seen in the present cliffs facing the lake." He thinks that the earliest ice-sheet had more grinding power than the ice-sheets of later cold periods ; but the till that overlies the fossiliferous interglacial beds indicates, nevertheless, the former presence of a very considerable ice-sheet, for the beds which it has spared are the mere fragments of what must have been widely extended deposits covering a broad region, from which they have since been entirely removed.

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[1] *Great Ice Age*, p. 466.

[2] *Canadian Journal*, April 1877.

Mr. Hinde tells me also that he has detected plant-remains in a similar position near Cleveland, Ohio. The deposits at this place are described by Dr. Newberry as his "pebbly Erie clay." They consist, my correspondent says, first, of till at the lake-level; secondly, of about 48 feet of sand and loam, containing a layer of plants ; and thirdly, of good unstratified till, 6 feet thick, full of striated stones.

I might easily refer to many examples of similar phenomena, but I need not enter further into details. It is enough for my immediate purpose to have pointed out that, in considering the origin of glacial and interglacial deposits, it is needful that more attention be paid to the distribution of these beds than has hitherto been done. This is the direction in which, as it seems to me, we must look for the key to the whole mystery ; indeed, I do not see how otherwise we are to arrive at any reasonable explanation of the phenomena. At the first blush it may appear hard to believe that a great mass of solid ice could ever pass over the surface of incoherent deposits of clay and sand. But the appearances presented by these deposits tell their own tale, and teach us, as we have been taught before, that our preconceived notions of what Nature's forces can and cannot do are often enough wide of the mark.[1]

It is needless to refer one to the petty glaciers of the Alps and Norway to prove that glacier-ice cannot both erode its bed and accumulate *débris* upon that bed at one and the same time. A mountain-valley glacier is one thing—a glacier extending far into the low grounds beyond the mountains, and, it may be, coalescing with similar extensive ice-flows, is another and very different thing. No considerable deposit could possibly gather below alpine glaciers like those of Switzerland and Norway; but underneath glaciers of the kind that invaded the low grounds of Piedmont and Lombardy we know that thick deposits of tough boulder-clay, crammed with scratched stones, did accumulate; and not only so, but that *these glaciers flowed over incoherent deposits of sand and clay containing marine shells of late Tertiary age, without entirely obliterating them.* The deposits referred to occur now as little patches within the area bounded by the great terminal moraines.[2]

As physicists themselves are not yet quite agreed upon the subject of glacier-motion, it is not incumbent upon the geologist to explain the precise mode in which a thick mass of ice can creep over the surface of incoherent beds without entirely demolishing them. It is enough for him to show how the remarkable distribution of the interglacial beds, and the various phenomena presented by these deposits, indicate that ice *has* overflowed them. It is needless, therefore, to tell him that the thing is impossible. The statement has been made more than once that an ice-sheet several thousand feet thick is a physical impossibility, but unfortunately for this dictum the geological facts have demonstrated that such massive ice-sheets have really existed, and there appears to be one even now covering up the

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[1] It may be doubted whether interglacial deposits, at the time they were overridden by ice, were as loose and incoherent as they are at present. My brother has suggested that, when the ice-sheet advanced over a land-surface, the loose superficial deposits might be frozen so hard as to be capable of resisting a very considerable degree of glacial erosion.

[2] See *postea*, Chapter XIII.

Antarctic Continent. We used also to be told, not so many years ago, that the abysses of ocean must be void of life for various reasons, amongst which one was that the pressure of the water would be too great for any living thing to endure. Yet many delicate organisms have been dredged up from depths at which the pressure must certainly be no trifle. Now there seems to be just as little difficulty in believing that these organisms existed in a perfect state at the bottom of the ocean, as that shells imbedded in clay would remain unbroken underneath the pressure of a superincumbent ice-sheet of equal or greater weight. If the ice were in motion, the clay with its included shells might be ploughed out bodily, or be merely crumpled and contorted ; or it might be ridden over with little or no disturbance ; or, on the other hand, it might become involved with subglacial *débris,* and be kneaded up and rolled forward—the shells in this case being broken, crushed, and striated, just as we find that the shells in certain areas of till have been. The fate of the fossiliferous beds would, in short, be determined by the rate of flow and degree of pressure exerted by the superincumbent quasi-viscous body—the motion of which would be largely controlled by the physical features of the ground across which it crept.

CHAPTER XIII.

INTERGLACIAL EPOCHS—*Continued.*

Interglacial deposits of Switzerland—Interglacial river-terraces at Camischollas—Glacial and interglacial deposits near Thoron ; at Dürnten and Utznach ; at the Bois de la Batie—Interglacial beds of Northern Italy—Ancient glacier of the Lago d'Iseo—Lacustrine deposits of the Val Borlezza—Deposits in the basin of Gandino—Lignites ot Leffe—Interglacial age of the lacustrine deposits of Val Borlezza and Val Gandino—Lacustrine deposits in Val Adrara and Val Forestro—Deposits in the Upper Val d'Arno—Interglacial deposits of Central France—Pumiceous conglomerate and associated deposits at Perrier, near Issoire—Glacial and interglacial deposits in the valleys of the Ain and the Rhone—Successive glacial epochs in the Vosges mountains—Two glacial epochs in the Pyrenees—Interglacial deposits at Gibraltar—Probable interglacial age of similar deposits in Malta.

We discussed in the preceding chapter the general evidence bearing upon the existence of interglacial deposits in Northern Europe, and the testimony they furnish as to changes of climate during the Ice Age. We have now to glance at the proofs which are supplied to us by the glacial accumulations of the central and southern regions of our continent in favour of similar climatic vicissitudes having formerly characterised those regions. Reference has already been made to the fact that M. Morlot, many years ago, had arrived at the conclusion that the glacial beds of Switzerland gave proof that there had been two periods of intense glaciation, separated by an intervening epoch of milder conditions. He showed that certain terraces, composed of water-worn gravel and sand, identical in all respects with modern river-deposits, occurred at heights varying from 50 to 150 feet above the present level of the streams. These terraces, there could be no doubt, were of fluviatile origin, and they indicated a time when the rivers flowed at considerably higher levels than those of the present day. One of these terraces borders the Rhine at Camischollas, above Disentis, at 4400 feet above the sea, and thus demonstrates that, at the time of its formation, the Alpine lands were free of ice up to that elevation at least. Now, in many places these ancient fluviatile deposits are found reposing upon glacial accumulations, and they are themselves frequently obscured under masses of a similar character. In the gorge of the Drance, near Thoron, the whole series is admirably exhibited. At the bottom is tough, compact boulder-clay, with striated stones, twelve feet thick, above which come 150 feet of well-bedded river-gravel and shingle, while these in turn are overlaid by an upper mass of boulder-clay, charged, like the lower deposit, with erratics and highly-glaciated stones. More recently, very interesting interglacial deposits have been detected in the neighbourhood of Zurich. At Dürnten and other places a bed of brown coal or lignite has been worked for a long time, and was, until recent years, generally believed to be of preglacial origin, from the fact that it is overlaid in places with morainic *debris* and erratics. It has now been proved, however, to be of interglacial age by the discovery that it rests upon boulder-clay. The lignites have been described in his usual luminous manner by Professor Heer.[1] They occur at Utznach in two layers, separated by beds of gravel and fine sand, and overlaid immediately by coarse shingle and gravel, surmounted by erratics. According to Heer, the lignites represent the swampy shores of an ancient interglacial lake, which, now and again overflowing its limits, deposited sediment above the vegetable soil, and thus gave rise to alternating beds of peat and loam, sand, gravel, etc. Among the plants which have been recognised by Heer are the following :—

Pinus abies (same as the common Swiss fir).
P. sylvestris, Scots fir (with trunks as thick as a man's body).

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[1] *Urwelt der Schweiz*, 2te Auflage, p. 513.

P. montana, mountain pine (agrees most nearly with *P. montana*, var. *humilis*).
P. larix, larch, probably.
Taxus baccata, yew.
Betula alba, birch (very common, most probably the same as the common Swiss birch).
Quercus robur, oak (uncertain whether *Q. pedunculata* or *Q. sessiliflora*).
Acer pseudo-platanus, sycamore or plane.
Corylus avellana, hazel.
Menyanthes trifoliata, bog-bean or marsh-trefoil.
Phragmites communis, common reed.
Scirpus lacustris, bulrush.
Rubus idæus, raspberry.
Polygonum hydropiper, water-pepper ; doubtful.
Trapa natans, water-chestnut ; doubtful.
Galium palustre, marsh bedstraw.
Vaccinium vitis-idæa, cranberry ; doubtful.
Holopleura victoria, a water-lily, not referable to any known existing species.

Besides these there are various mosses, such as *Sphagnum cymbifolium, Hypnum lignitorum, H. priscum, Thuidium antiquum*, etc., and a horsetail reed (*Equisetum limosum ?*)

The osseous remains associated with the lignite represent :

Elephas antiquus.
E. primigenius.
Rhinoceros Merckii, Jæg.[1]
Bos primigenius.
Cervus alces.
Cervus elaphus.
Ursus spelæus.

In the same beds occur numerous shells belonging to a few species: such as *Pisidium amnicum*, Müll., *Valvata obtusa*, Drap., and a variety of *V. depressa*, Pfr., together with fragments of *Anodontæ*. Insect-remains are also abundant, and include *Donacia sericea, D. discolor, Hylobius rugosus*, and several predacious ground-beetles.

The intercalated position of the Swiss lignites leaves no room for doubt that the beds are of interglacial origin. They show us that after the great glaciers had for a long time occupied all the low grounds of Switzerland, and even deployed upon the plains of France and of the Danube, they at length melted away, leaving the ground covered with boulder-clay and with sheets and heaps of shingle, gravel, and sand, and sprinkled with large isolated erratics. The climate gradually became milder, and a flora resembling that of to-day covered the Swiss lowlands. Man was at that time probably an occupant of the country, as is shown by the discovery in the lignite of several small-pointed rods, which are believed by Rütimeyer and others to have formed part of some basket- or wattle-work. How long this mild interglacial epoch lasted we cannot tell. But its protracted duration may be inferred from the thickness attained by the brown coal. This, according to Heer, would require some 6000 years for its formation. Whether this estimate be over or under the truth, it serves to show that the lignite could not have accumulated between one of the comparatively rapid retreats and advances which characterise the present Swiss glaciers. The overlying morainic matter proves that the Linth glacier again advanced—and that to a considerable distance—for its terminal moraines are found at the lower end of Lake Zurich. It ploughed down through the interglacial and older glacials beds, sweeping them out of the bottoms of the valleys, and leaving only shreds and patches of them fringing the hill-slopes. This is very well exhibited at Utznach, where, standing at the coal-mines which are driven into the hill-slope, we look down into the valley at the head of Lake Zurich and see the terminal moraines left during the retreat of the Linth glacier, forming heaps and ridges. The lignites and freshwater sands and clays evidently mark a former much higher level of the lake, which must at one time have extended across the valley to a similar elevation on the opposite side, where, indeed, patches of the same old freshwater deposits have been detected. The latest advance of the glaciers resulted, therefore, in the lowering of the lake-level, and the demolition of the interglacial land-surface.[1]

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[1] See *ante*, footnote, p. 262.

[1] For some further account of the occurrence of Pleistocene lignite in and

Yet another example to show that there have been more than one great invasion of the low grounds of Switzerland by ice. At the Bois de la Batie above the confluence of the Arve with the Rhone, near Geneva, thick boulder-clay is seen resting upon conglomerate or hardened river-gravel. This latter bed is, unquestionably, the ancient alluvium of the Rhone. Is it, then, preglacial? Its contents shall answer for us. Here are a number of stones which could only have been derived from the upper valley of the Rhone, such as the euphotide from the valley of Saas, in Valais. It is quite impossible that the Rhone could have carried them into their present position, for the deep cavity of Lake Leman (334 mètres) intervenes. We must perforce agree with M. Tardy, who remarks, that "a glacier is in fact the only vehicle which could have transported them across the lake from their parent rocks in Valais." And that this glacier was not the same as that which buried the ancient alluvium underneath its boulder-clay is proved by the fact, mentioned by Professor Favre, that the ancient river-gravel, at the time of the last advance of the glaciers, had already been cemented into a hard conglomerate, and was striated and polished just like any other indurated rock-mass. Not only so, but it had been cut down and highly denuded and worn into terraces by running-water long before the last great *mer de glace* overflowed it. It is further worthy of note that the ancient river-gravel rests upon marly clay with freshwater-shells and traces of plants. These facts show us that before the formation of the ancient gravel and its associated deposits, the Rhone glacier must have filled up the basin of the lake and strewed the ground at its lower end with morainic detritus derived from Valais. Then came a period when the glacier disappeared and its morainic deposits were waterworn and re-arranged, and distributed over a wide area in the neighbourhood of Geneva. In later ages the ancient alluvium was denuded and trenched by the streams cutting their

under boulder-deposits in Switzerland, see *Zeitschr. deutsch. geol. Ges.*, 1880, p. 84, where Professor Credner describes and figures certain sections which were observed many years ago by Escher von der Linth and A. Heim.

way down to lower levels. Meanwhile, what was once more or less loose gravel had become cemented into hard pudding-stone. Then came the last glacial epoch, when the glacier of the Rhone re-advanced, and, grinding over the surface of the hardened "alluvium," scratched and polished it, and eventually covered it up with boulder-clay.[1] The ancient alluvium of the Bois de la Batie is thus, in all probability, of the same age as the Dürnten lignite and gravel beds.

Some interesting deposits recently discovered by Dr. Greppin, near St. Jacob, in the Birsthal, not far from Basel, are believed by Professor Heer to be likewise of interglacial age. The beds consist of a considerable thickness of gravel and shingle (80 to 90 feet), with an interstratified layer of clay, over three feet thick, which has yielded plant-remains, such as pine (*Pinus sylvestris reflexa*, Hr.), white birch, hazel, hornbeam, two willows (*Salix cinerea* and *S. aurita*, L.), cranberry, bog whortleberry, bog-bean, privet, common dogwood, black alder, etc.—all the species being still indigenous to the low grounds of Switzerland, and, with the exception of the bog whortleberry, to the Birsthal. The same bed yields a few insects and many shells, such as—

Helix hispida.
,, *arbustorum.*
,, *pulchella.*
,, *crystallina.*
,, *edentula.*
,, *montana.*
Planorbis vortex.
,, *spirorbis.*
,, *carinatus.*
Physa hypnorum.
Succinea oblonga.
Carychium minimum.
Clausilia parvula.
Pupa marginata.
,, *secale.*
Limnæa minuta.
Vitrina elongata.
Cyclas fontinalis.
,, *rivalis.*

From another bed of gravel in the same valley, which is a continuation of the upper gravel-beds of St. Jacob, Dr. Greppin has recorded remains of the mammoth and the urus (*Bos primigenius*), and some land-shells.[1]

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[1] For descriptions of this interesting section see A. Favre, *Bull. Soc. Géol. France*, 3e Sér. t. iii. p. 657 ; Ch. Lory, *Ibid.*, p. 723 ; M. Tardy, *Ibid.*, t. iv. p. 182.

A bed of lignite, similar to that of Utznach and Dürnten, is found at Chambéry and Sonnaz in Savoy. It is interstratified with beds of clay and gravel, which repose upon an unknown depth of fine sand, and are covered by 100 feet of glacial deposits. From the character of the vegetable and insect remains in the lignite and clay, and from the geological position of the deposits, they are believed to be of the same age as the interglacial lignites of Switzerland.

The climate of the interglacial epoch, during which those lignites were accumulated, appears to have been not unlike that of the same regions at the present day, and the antiquity of the deposits is shown by the presence of the extinct forms of plant- and animal-life.

In certain of the Alpine valleys of Northern Italy we again encounter lignites associated with old glacial deposits, which present some very interesting features. The most important, from our present point of view, are those which occur at Leffe, in the basin-shaped valley of Gandino that opens upon the Val Seriana, and the similar but less well-developed lignites of the Val Borlezza, whose stream discharges into Lake Iseo. The deposits have been admirably described by Professor Stopanni, whose observations I have to a certain extent corroborated by a personal examination of the ground.[2]

The Lago d'Iseo, as is well known, has formerly been filled by a great glacier that descended from the higher Alps by the Valle Camonica, and advanced for some distance into the plains of Lombardy, where its terminal moraines now form the crescent-shaped line of hills known as the Colline della Francia Corta [See Plate B].[3] When the glacier reached its greatest development it sent off a branch which left the main trunk near the foot of the Val Borlezza, and, passing west and south-west by the Valle Cavallina, descended as far as the village of Entratico on the banks of the river Cherio, a few miles above Trescorre. At the foot of the lake the main glacier was divided by the Colle d'Adro, the largest mass flowing south between Iseo and Clusone towards the Colline della Francia Corta, and the shortest and narrowest limb extending west by Sarnico down the present course of the Oglio as far as Calepio. Several of the little lateral valleys which drain into Lake Iseo do not appear to have supported glaciers of their own, but were simply dammed up by the great glacier of the Valle Camonica as it flowed past them on its way towards the plains. This was the case with the Val Borlezza, which now opens upon the lake at the gorge of Castro, not far from the head of the lake; and the smaller valleys of Adrara and Forestro, near Sarnico, at the foot of the lake, are examples of the same phenomenon. The valleys referred to were thus converted into lakes, upon the beds of which quantities of mud and loam were deposited. While the great glacier was melting away the lakes in these side valleys were drained, and the streams, resuming their work of erosion, eventually cut their way down to the bottom of the old lacustrine sediments, which are thus exposed to us in fine sections. One can see at a glance that the Val Borlezza is only the bed of a dried-up lake, now deeply incised by the stream which has dug its way down to a depth of more than 200 feet from the surface to join the Lago d'Iseo. In the sections disclosed by the stream below Pianico the lacustrine strata, consisting of silt, clay, and sand, in horizontal layers, are underlaid by morainic deposits charged with many glaciated and striated stones. At Pianico the lacustrine clay and sand are overlaid by a mass of white marl—a kind of calcareous *tripoli,* as Stopanni describes it,—abundantly charged with the limy skeletons of microscopic organisms. This deposit has yielded abundant remains of plants and fish, together with those of a rhinoceros (*R. hemitœchus,* Falc.), determined by Dr. Forsyth Major. The fish have not yet been studied, and our knowledge

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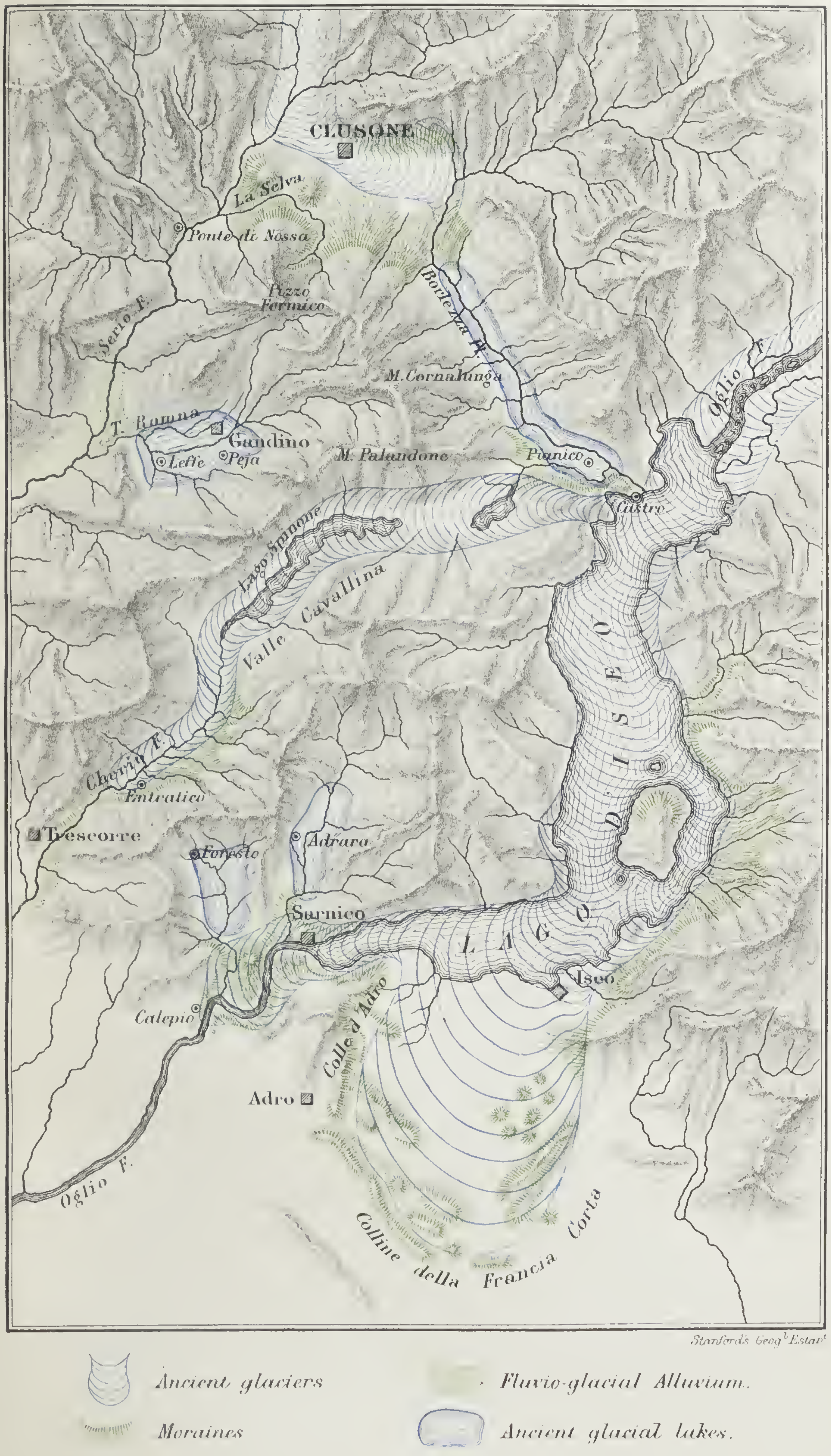
[1] *Urwelt der Schweiz*, p. 532.

[2] *Corso di Geologia*, vol. ii. p. 657 *et seq.*; *Geologia d'Italia*, per A. Stopanni et G. Negri, Parte II., p. 243 *et seq.*

[3] Plate B is taken from Stopanni's *Corso di Geologia*.

GLACIAL SYSTEM OF LAKE ISEO.


CLUSONE
La Selva
Ponte di Nossa
Pizzo Formico
Serio F.
Borlezza R.
M. Cornalunga
T. Romna
Gandino
Leffe
Peja
M. Palandone
Pianico
Castro
Oglio F.
Lago Spinone
Valle Cavallina
LAGO D'ISEO
Cherio F.
Entratico
Trescorre
Foresto
Adrara
Sarnico
Iseo
Calepio
Colle d'Adro
Adro
Oglio F.
Colline della Francia Corta
Ancient glaciers
Moraines
Fluvio-glacial Alluvium.
Ancient glacial lakes.

Stanford's Geog^l Estab^t

of the plants is still incomplete, but the following have been recognised by Sig. Sordelli :—

Magnolia, Sp.
Acer pseudo-platanus, L., var. *paucidentata*, Sand.
Buxus sempervirens, L.
Ulmus campestris, L.
Taxus baccata, L.
Phacidium buxi, Westdp. (parasitic on the leaves of the box).

Above this highly fossiliferous marl come massive accumulations of morainic detritus with large erratics. The complete section at Pianico is thus in descending series as follows :—

1. Glacial morainic deposits.
2. Lacustrine marl with *Rh. hemitœchus*, etc.
3. Clay passing down into silt and sand, which contain scattered and sporadic stones.
4. Sand, etc., abundantly charged with glaciated stones.

At what was formerly the head of the ancient lake the river has exposed a seam of impure lignite, intercalated among deposits of silt and sand.

Stopanni has demonstrated that this ancient lake owed its origin to the damming up of the gorge of Castro, through which the river Borlezza makes its way into Lake Iseo. The height to which the mountain-slopes are glaciated, and the elevation reached by the lateral moraine of the glacier that dammed the valley, show that the icy bar rose to a level of more than 300 feet above the present surface of the lacustrine deposits of the Val Borlezza. Enormous quantities of morainic *débris* were toppled over the side of the glacier into the lake of the Val Borlezza, while quantities of striated stones, along with sand and mud, were extruded upon the bed of the lake from the bottom of the glacier. At this time the stream flowing into the old lake of Borlezza was swelled by muddy torrents escaping from the ancient glacier of the Val Seriana, which then occupied the basin of Clusone, and thus the bed of the lake came in time to be covered with layers of mud and silt and sand, which gradually attained a thickness of several hundred feet. While these conditions obtained, the valley-slopes in the neighbourhood, according to Stopanni, were clothed with magnolias, sycamores, box-trees, yews, and so forth,—the rhinoceros wandered along the margin of the lake, and fish abounded in its waters. This, however, was before the glacier had reached its greatest development. "The glacier," he says, "continuing to increase, dilated into the Val Borlezza. The lake, now partially silted up with its own sediment, had become diminished in extent, and the morainic *débris* fell from the side of the glacier upon the surface of the lacustrine deposits," and then the ice finally melted away and permitted the river Borlezza to drain the lake, and eventually to cut a deep trench down through the ancient lacustrine deposits. Thus, in Stopanni's opinion, all the lacustrine beds of the Val Borlezza belong to a period when the gorge of Castro continued to be dammed with ice, and we are to believe that a rich flora, indicative of a climate not less, nay, according to Sordelli, even more, genial than that now enjoyed by the same valley, clothed the hill-slopes, while the great glacier of the Val Seriana filled the broad hollow that extends from Clusone to the river Borlezza. Again, we are to suppose that this ancient lake—dammed with ice, fed by muddy water flowing directly from a glacier, and by numerous lateral streams descending from snow-covered mountains — was nevertheless tenanted by many fish and microscopic organisms, whose calcareous skeletons gave rise to an accumulation of pure white marl.

With these conclusions I cannot quite agree; but before giving my reasons for this dissent I will describe first the phenomena presented by the famous lignites of Leffe, in the basin of the Val Gandino, which drains into the Val Seriana. The upper section of the Val Seriana has formerly been occupied by a large glacier, which descended as far as Clusone, where it abutted upon the flanks of the Pizzo Formico, a massive mountain, which separates the Val Seriana from the Val Borlezza. Here the ice-flow divided, a portion spreading into the Val Seriana, but the main mass creeping eastward, so as to occupy the wide open space that extends from Clusone to the

Val Borlezza. It was the muddy water derived from this glacier which, it will be remembered, fed the glacial lake formed in the last-named valley by the ice-dam of the Camonica glacier. From that portion of the glacier which dilated into the lower reaches of the Val Seriana enormous quantities of shingle, gravel, and sand were carried down by the river, forming banks and terraces, which are seen fringing the flanks of the valley up to a great height above its present bed. These can be traced down the valley beyond the mouth of the Val Gandino, across which they extend, forming a great bar, which, as viewed from the road in the Val Seriana, has all the appearance of a huge moraine. One's first thought, indeed, is that this lofty bar has been thrown down as the frontal moraine of an ancient glacier, which may formerly have occupied the basin of Gandino. But Stopanni has shown that the bar is made up of shingle, gravel, and sand, the greater portion of which has come down the Val Seriana, and could not possibly have been derived from the Val Gandino. His opinion is, that the embankment was thrown down by the Serio itself; that in short it is only a portion of the enormous deposits of fluvio-glacial detritus which were swept down the valley when its upper reaches were occupied by the ancient glacier that descended as far as the Ponte di Nossa. When the glacier was at this point, says Stopanni, the fluvio-glacial detritus, always strongly developed in the region which a glacier approaches, extended from the Ponte di Nossa until well beyond the opening of the Val Gandino; it rose high upon the slopes of the narrow valley in which the Serio runs, between the great moraine of La Selva and the mouth of the Gandino basin, and thus barred the latter, and converted it into a lake. My own observations enabled me to confirm these views of the able Italian geologist. There can be no doubt, I think, that the bar of shingle, now hardened into conglomerate, which is thrown across the opening of the basin of Gandino or Leffe, is only a great *cône de déjection* of the Serio, formed at a time when that river was enormously swollen by the water escaping from melting snow and ice. The embankment presents a steep face now to the Val Seriana, for it has been undercut by the Serio in the process of lowering its bed. But its upper surface still slopes in from the Val Seriana towards the basin of Gandino, and I could notice here and there that the coarse shingle of which it is made up had the same general inclination.

Viewed from the top of the embankment, the basin appears like a concave plain, bounded on every side by rough, steep mountains ; it has all the aspect, indeed, of an old lake-bottom, drained by the Romna, which now flows in a rocky glen at a depth of over 300 feet below the summit-level of the bar, down through which it has cut its way.

The whole surface of the basin appears to be covered with shingle and gravel, now for the most part hardened into conglomerate, consisting of rocks which are all of strictly local origin, derived in fact from the limestone and porphyry of the adjacent mountains. This conglomerate is well exposed in all the numerous ravines and gorges which the streams have cut out in the bed of the old lake, and appears to attain a very considerable thickness. In the neighbourhood of Leffe, which is near the lower end of the basin, I should say it must exceed 150 feet.

Underneath the conglomerate come beds of fine lacustrine clay, silt, and shell-marl, with one or more seams of brown coal or lignite, of which Stopanni gives the following section, disclosed in one of the pits near Leffe :—

	Mètres.
1. Vegetable mould . . .	1·0
2. Gravel	2·0
3. Plastic clay	3·5
4. Clay with shells . . .	10·0
5. Impure lignite . . .	1·0
6. Shell-bearing clay . . .	20·0
7. White clay	2·0
8. Lignite, principal seam . .	9·5
9. Black, shelly clay . . .	3·0
	52·=about 170 feet.

The lignites appear to be composed for the most part of the remains of trees; they are almost black, and somewhat fissile. Sometimes the upper surface of the principal seam consists of a mass of trunks and branches confusedly interlaced, which evidently had grown *in situ;* at other times the lignite would give one the impression that it had been laid down in water. The absence of impurities, however, might perhaps indicate that the formation took place on the low, marshy shores of a still sheet of water, which now and again rose in level, and so caused mud and marl to gather over the surface of its peaty margins; but according to Stopanni, the whole is nothing but floated wood, which has been deposited in the bed of a lake.

Sordelli gives the following list of plants obtained from the lignites of Leffe:—[1]

Pinus, sp.
Abies excelsa.
,, *Balsami*, Sord.
Larix europæa, D.C.
Corylus avellana, L.
Acer tribulatum (?), Stern.
Æsculus hippocastanum, L.
Juglans bergomensis, Bals.
Trapa natans, L.
Folliculites newirthianus, Mass.

The walnut-tree seems to have grown luxuriantly, and its remains are perhaps more abundant than those of any of the other species named by Sordelli. During my visit to one of the "opencast workings," I picked out several walnuts within the space of a yard or two. The flora of the Leffe lignite does not contradict that of the Val Borlezza; it indicates a climate which, according to Sordelli, was certainly not cold, but as genial as that of the plains of Lombardy and Venetia.

A number of mammalian remains have been found associated with the lignite beds, and referred by Dr. Forsyth Major to the following species:—

Elephas meridionalis, Nesti.
Rhinoceros leptorhinus, Cuv. (=*R. megarhinus*, De Christol.)
Bos etruscus, Falc.
Cervus; two species.
Castor europæus (?).
Arvicola, sp. (not. *A. agrestis*).

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[1] *Atti Soc. Ital. Sci. Nat.*, v. xvi. (1874), p. 350.

All the shells belong to species still living in Lombardy (*Valvata piscinalis* and *Planorbis complanatus*).

Stopanni is of opinion that the lignite and its associated deposits were accumulated at the very time that the Serio was engaged in piling up the great embankment across the mouth of the Gandino or Leffe valley. He thus relegates the growth of the lignites to a glacial epoch, which is of course consistent with his views of the origin of the lacustrine deposits of the Val Borlezza. Referring to the lignite of the principal seam, he says, "I am of opinion that this wood is nothing but drifted wood deposited in the bosom of the lake. How could this be if all the mountains were very precipitous and desolately bare? I think that the lacustrine plain would be found sometimes either entirely or in certain places converted into a marsh, where the forests of walnuts (I speak of the principal constituents) would be condensed perhaps for ages, until they were submerged by the waters, which would gradually rise on all sides as the *cône de déjection* which dammed the lake continued to increase in height." The final filling up of the basin he attributes to the action of torrents carrying down shingle and gravel from the surrounding hills, and thus gradually pushing out their deltas, until little by little they gradually filled up the hollow, and converted it into a wide alluvial plain.

The overlying conglomerate is no doubt of torrential origin, but I do not believe it has been formed in the manner suggested by Professor Stopanni. It is disposed in broad terraces, the upper surfaces of which are inclined outwards or down the Val Gandino to the gorge of the Romna, which now separates the great bar from the mountain-slope, against which, according to Stopanni, it formerly abutted. The whole surface of the basin in fact forms an inclined plane that rises gently towards the foot of the mountains east of Gandino. This plane is deeply cut and trenched by the numerous feeders of the Romna, in which capital sections of the overlying conglomerate are exposed, and the beds are there seen to have the same low dip towards the mouth of the valley. The whole of these ancient shingle- and gravel-deposits indeed present the appearance of having been spread over the bottom of the valley by torrential streams flowing chiefly from the mountain-valleys above Gandino (Val Tuona, Val Concosola, and Val Piana), swelled by streams coming from the hills behind Peja and Leffe.

These appearances, and others which will presently be described, lead me to conclude that the conglomerate belongs to a period long subsequent to the silting-up of the lake. In the pits at Leffe its junction with the underlying lignite-beds is well exposed, and the latter are there seen to have been much denuded before they became buried under the tumultuous shingle that overlies them. There is no dovetailing or interosculation of fine and coarse sediment, such as we might have expected to find had the lake been gradually filled up in the manner supposed by Stopanni; but the lacustrine beds are abruptly separated by a clearly-defined line of demarcation from the coarse deposits above. The annexed sketch-section will exhibit the general features referred to. Here, it will be observed, a mass of coarse gravel and shingle, horizontally bedded, or approximately so, and reaching a thickness of 30 to 50 feet, lies directly upon the truncated edges of the lacustrine deposits. The lower portions of the conglomerate-beds contain lines of sand, with fragments of lignite, evidently derived from the denudation of the underlying strata. The conclusions I

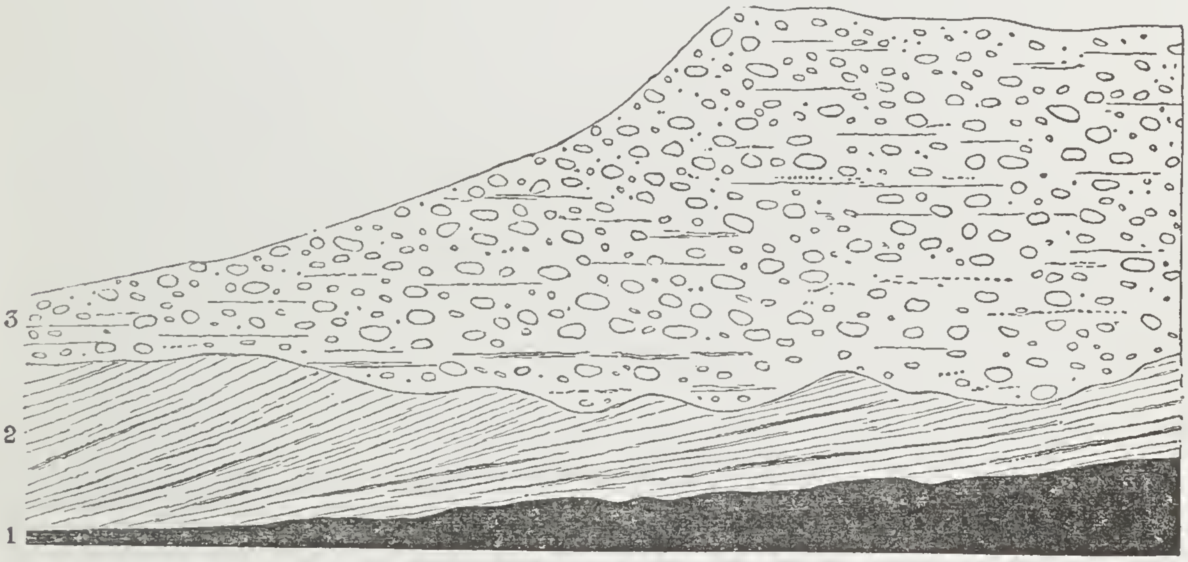

Fig. 9.—Section of Lignite, etc., Leffe, near Gandino.
1, Lignite; 2, Silt, clay, etc.; 3, Shingle.

formed from a study of this and other sections in the neighbourhood were shortly as follow :—

1. That the lignite and its associated deposits were accumulated in a lake which they succeeded gradually in silting up.

2. That, afterwards, flooded streams and torrents flowed over the surface of the dried-up lake, ploughing at first into the lacustrine sediments, but eventually burying them deep under a great accumulation of coarse shingle and gravel.

3. That a time came when this extreme torrential action ceased, and the streams thereafter commenced to erode their beds, and to cut deep trenches down through the conglomerates into the lacustrine sediments.

The conglomerates, I have no doubt, are, as Stopanni maintains, of precisely the same age as the morainic detritus which overlies the white marls of Pianico in the Val Borlezza. They belong, in short, to a glacial epoch, when torrential water, derived from melting snow and *névé,* descended in great volumes from all the hills surrounding the basin of Leffe. Unfortunately the section at Leffe does not disclose the nature of the bottom upon which the lacustrine sediments repose. In the Val Borlezza, as we have seen, the lower part of the lacustrine deposits is abundantly charged with glaciated stones. No glaciated stones, however, occur in the neighbourhood of Leffe. I believe, however, with Stopanni, that the great embankment thrown across the opening of the valley is unquestionably of fluvio-glacial origin. To this view Professor Rütimeyer has objected that the Romna at its exit from the Val Gandino flows over limestone and not conglomerate.[1] This is true, and it is no less certain that the basement-beds of the lacustrine series must be under the level of the Romna, where it first begins to flow across the limestone-strata. But we have no reason to suppose that the present exit of the river was that which obtained in preglacial times. When the Val Gandino was dammed up by the *cône de déjection* of the Serio and converted into a lake, the old course by which the Romna escaped into the Val Seriana may have

[1] *Ueber Pliocen und Eisperiode auf beiden Seiten der Alpen.*

been considerably farther north than the present. Its interglacial and postglacial course would be determined by the contour of the *cône de déjection* across which the lake would overflow at the lowest part, which, of course, need not have coincided with the preglacial course of the Romna.[1]

But while I agree with Stopanni that the lake was formed in the way he supposes, I cannot go with him when he maintains that all the lacustrine deposits were laid down during the piling up of the embankment, that is to say, in other words, during a glacial epoch. The character of the flora and fauna of Leffe and Borlezza will not permit of this supposition. It is impossible to believe that at a time when all the great valleys of the Alps were filled to overflowing with enormous glaciers, many of which deployed upon the plains of Piedmont, Lombardy, and Venetia, and when all the low grounds of Switzerland were buried under an enormous *mer de glace*, which flowed north to within a few miles of the Danube, and descended in the west to the low-lying tracts of Dauphiny, it is impossible, I think, to believe that at such a time the climate of two mountain-valleys like the Val Gandino and the Val Borlezza could have supported a rich flora, comprising magnolia, box, walnut, etc., or had for their occupants elephants, rhinoceroses, oxen, and deer. Nor do the stratigraphical appearances justify us in holding such a view. The lignites, with their associated shelly clays and marls, are of interglacial age—they separate in fact two glacial epochs. During the first of these epochs we may believe the Serio to have blocked up the Val Gandino with its *cône de déjection*. The glaciers then melted away, and perennial ice was confined to the upper reaches of the valleys, as it is to-day. While the river Serio sank to a lower level, the Romna, escaping from the Val Gandino, gradually cut its way across the dam or bar, and thus reduced the level of the Leffe lake, until eventually, partly by this process of drawing off the water, and partly by the deposition of fine silt, the lake became restricted in size, and vegetation ere long crowded its margin. The beds above the lowest lignite indicate a rising of the lake, consequent, probably, upon a corresponding increase in the volume of the Serio. The next bed of lignite points to a pause when the surface of the lake was again encroached upon by the growth of vegetation. Once more, however, the waters began to rise, and freshwater clays were deposited upon the surface of the now submerged peat. But as the climate deteriorated, and a glacier again filled the upper part of the Val Seriana, the former conditions returned. Great torrents derived from melting snow and *névé* poured down the Val Gandino, tearing up the lacustrine sediments, and eventually burying them under great sheets of shingle and gravel. The Serio at the same time may have partially choked up the gorge of the Romna with its shingle and gravel, but it did not succeed in again converting the Val Gandino into a permanent lake.

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[1] Another view suggests itself as a possible explanation of the phenomena. The lacustrine deposits may occupy an old rock-basin. The appearances in the valley below the lignite-workings do indeed seem to indicate as much. But if so, how was that rock-basin formed? The geological structure of the valley hardly admits of us supposing that the limestones may have been undermined by acidulated waters, and so have given rise to a rock-hollow by subsidence. Nor have we any evidence of glacial action to lead us to infer that the hollow might have been excavated by a local glacier. The mountains surrounding the Val Gandino show no trace of glaciation; no erratics occur, neither did I encounter any in the Val Seriana below the confluence of the Romna with the Serio.

The phenomena exhibited in the Val Borlezza are quite in keeping with these conclusions. The lake of Borlezza unquestionably owed its origin to the blockage caused by the glacier of the Val Camonica and that arm of it which crossed over into the Val Cavallina. The bottom-beds of the lacustrine series are composed of true glacial clays and silt, containing in the deep cutting below Pianico scattered glaciated stones, which become more numerous towards the base of the section, where the sandy mud or muddy sand is most abundantly charged with them. All these deposits must have gathered there while the mouth of the valley was barred by the glacier. Eventually, however, that glacier melted away, and left behind it an embankment of morainic detritus, which for some time would continue to act as a bar ; but the lake, as it overflowed, would sooner or later cut that impediment across and so drain itself. The process of excavation would, however, be more tedious than might at first be supposed. The remains of the bar are still found clinging to the slopes of the mountains in the form of a mass of indurated conglomerate and coase *débris*. It is highly probable that long before the glacier had disappeared much of its moraine may have become thus hardened by the infiltration of superficial water. Many of the rock-fragments consist of limestone, while the hills around are composed largely of calcareous strata. We are not to suppose, therefore, that the bar of morainic detritus would be as readily removed as one composed of the *débris* of crystalline rocks in a country where the superficial water contains only a very small percentage of calcareous matter. And the same remarks apply to the bar across the mouth of the Val Gandino, which is a mass of more or less indurated conglomerate. A shallow lake, therefore, would continue to exist for some time during the genial epoch that supervened after the dissolution of the glacier in the Val Camonica. It was then that a rich flora crept up the Alpine valleys from the plains of Italy, and the great Pleistocene mammals found a congenial home in such secluded vales as that of Clusone and the Val Borlezza. The lake, no longer turbid with glacial mud, now favoured the accumulation of pure white marl, and fish abounded in its waters. But eventually these genial conditions came to a close; the mammalia retreated, the rich vegetation disappeared. Once more the Val Camonica filled with ice, and the glacier dilating into the Val Borlezza threw its lateral moraine upon the surface of the interglacial deposits. The advent of milder conditions and the final dissolution of the glacier then permitted the river Borlezza to cut its way down into the deep narrow trench through which its waters now rush to join the Lago d'Iseo.

The Val Adrara and the Val Forestro each contain relics of ancient glacial lakes which from Stopanni's description would appear to have experienced the same cycle of changes as the larger valleys which I have just described.

Thus on both sides of the Alps we have evidence to show that the Glacial Period was not a long uninterrupted period of cold conditions, but that it was characterised by oscillations of climate, comparable with those which marked the Ice Age of the British Islands and Northern Europe. It is true that hitherto we have discovered evidence in Switzerland and Italy of only one interglacial epoch. We are not, however, justified in concluding from this that only one such epoch interrupted the Glacial Period—that the glaciers only twice invaded the low grounds. The positions in which the Italian and Swiss lignites have been preserved are wholly exceptional. The Val Borlezza could only be converted into a lake by a glacier blocking its mouth, and this happened twice. But there may have been glacial epochs both earlier and later, when the glaciers did not extend so far. Of such cold epochs and of the milder eras which may have separated them, the Val Borlezza might well preserve no recognisable trace. And the same may be said of the basin of Leffe. A mountain region, as I have remarked above, is the least likely in which to look for the relics of interglacial times. The very places (viz. valley-bottoms) in which freshwater beds would be deposited, are just those adown which the glaciers of a succeeding cold epoch would advance, crushing, grinding, and ploughing on their way. The conditions under which the lignites of Leffe and the Val Borlezza have been accumulated were thus, as I have said, quite exceptional—they owe their origin more or less directly to the former great extension of the glaciers, but their preservation is due to the fact that the valleys in which they occur were not ploughed out by glacial action.[1]

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[1] It is still an open question whether the great frontal moraines of the plains of Piedmont, Lombardy, and Venetia, mark the extreme limits reached by the glaciers during the climax of the Ice Age. These moraines are underlaid by great accumulations of coarse gravel and shingle, much of which no doubt was laid down by rivers flowing from the glaciers at the time of their advance. But all the shingle-beds, which are frequently hardened into conglomerate, cannot be so accounted for. I refer especially to those wide-spread masses of conglomerate, which are called *Ceppo* by the Italian geologists, and assigned by them to the Pliocene Period. Through these deposits the glaciers have ploughed their way in precisely the same manner as the glaciers of the latest glacial epoch in Swit-

There are certain other Italian freshwater deposits which have yielded many mammalian remains belonging to the same fauna as that of Leffe and Borlezza. I refer to the freshwater beds of the Upper Val d'Arno between Florence and Arezzo. There are two series of deposits in that region, the lower of which is composed of blue clays, whitish sandy marls, and yellow sands, more or less argillaceous and ferruginous. These beds have yielded remains of *Mastodon longirostris* and *M. arvernensis*, together with plants and certain freshwater-shells, belonging to characteristic Pliocene types, and are therefore older than any of the glacial and interglacial deposits we have been studying. Above them, however, comes a group of beds of which the most characteristic is a conglomerate locally known as "Sansino," formed of nodules of clay, and other small concretionary masses, commingled with little angular fragments of various kinds of rock, and bits of mammalian bones. A bed of this "Sansino" forms the base of the upper group.[1] Above it comes a thick series of sands, gravels, and various-coloured clays in alternate layers, which are characterised by abundant remains of the Pleistocene mammalia—amongst which are *Elephas meridionalis*, *Rhinoceros leptorhinus*, *Hippopotamus major*, *Ursus etruscus*, *Equus Stenoni*, *Bos etruscus*, and several deer, such as *Cervus*

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zerland have dug a course for themselves through the interglacial and glacial deposits of earlier times. Now the Ceppo is of precisely the same character as the so-called "alpine diluvium," and would thus appear to have had a similar origin. It would in this view represent the flood-gravels of an early glacial epoch—the frontal moraines of which have long since been demolished by the action of the Po and its numerous tributaries, just as those of the ancient Rhone glacier have to a large extent vanished from the plains of France. It is quite possible, indeed, that many of the erratics which are scattered over the hills of Turin may have been carried thither by glaciers during the climax of glacial cold. This possibility occurred to me when I first visited that district some years ago, and subsequent explorations have tended to confirm my suspicion that the erratics of the Superga have not all been derived from the destruction of the great Miocene conglomerate-beds. When I first made this suggestion (1871), I was not aware that I had been anticipated by Dr. Julien.—See *Des Phénomènes Glaciaires dans le Plateau Central de la France* (1869), p. 50.

[1] Professor Mayer insists upon the existence of a clear line of demarcation between the Pliocene and Pleistocene deposits of the Val d'Arno. See *Bull. Soc. Géol. France*, 3e Ser. t. iv. p. 208 *et seq.*

dicranios, C. pectinatus, etc.—a fauna, in short, comparable with that of Leffe and Borlezza. Now, without going so far as to say that the beds of "Sansino" may be of fluvio-glacial origin, their occurrence is at least suggestive of powerful aqueous erosion and transport. And the fact that they are so closely associated with beds containing the same fauna as that of the interglacial deposits referred to is not without its significance, as indeed Dr. A. Julien pointed out some years ago. Before leaving the subject of Italian Pleistocene, I may note the discovery at Olmo, in the plain of Arezzo, of the human skull referred to at page 22. It was found in a bed of blue clay underneath a layer of lignite, over which came blue clay of the same character as the bed below. Above the whole are beds of sand. The blue clays contained many freshwater-shells—all of living species—and the upper one yielded a tooth of *Elephas meridionalis.* In the overlying sandy deposits were discovered remains of *Cervus megaceros, Equus caballus,* and other well-known Pleistocene forms.[1] The skull thus pertains to Pleistocene times—to the period during which *Elephas meridionalis* belonged to the European fauna.

At the hill of Perrier, near Issoire, in the valley of the Allier, are found certain interesting sections, the meaning of which was first ascertained by Dr. A. Julien.[2] Deposits of Miocene and Pliocene age are here found overlaid by a thick "pumiceous conglomerate," the contents and character of which betray its glacial origin. It is composed of a heterogeneous aggregation of large and small fragments of different kinds of rock, embedded in a yellowish loam which weathers very readily, the loam disappearing with every shower of rain, and leaving behind the sand, grit, gravel, and blocks which it contained. The size of the blocks is considerable. Bravard measured one of more than 6000 cubic mètres, and Julien mentions another which had a circumference of 27 mètres. He states also that fragments a cubic mètre in volume may be counted by thousands. All the stones, large and small alike, are angular, and many are covered with glacial striæ. They are scattered pell-mell, higgledy-piggledy, through the tuff-like loam in which they occur, and in places where they are closely aggregated irregular cavities occur between the blocks, showing that the stones were rudely heaped and piled up in the same manner as the *débris* of a moraine. The fragments consist of many different kinds of rock, such as granite, trachyte, basalt, and Miocene limestone, all of which have been derived from Mont Dore and the adjacent neighbourhood. The only rock of the district which is not represented in the "conglomerate" is the modern lava of Montchalm. On the other hand, some stones, the parent rock of which is unknown in place, occur in considerable numbers. Such are blocks of a peculiar pumice which abound at Perrier, and fragments of certain trachytes and conglomerates. There can be no doubt, however, that all these belong originally to Mont Dore, the beds of which they once formed a portion having been destroyed by the glacier which transported the *débris* to its present position. The largest blocks that occur in this remarkable glacial accumulation are all trachytes which have travelled from Mont Dore, a distance of 25 kilomètres.

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[1] Cocchi: L'uomo fossile nell' Italia centrale, *Mem. della Soc. Ital. di Scienze naturali* (1867); Forsyth-Major, *Archiv. per Antropologia e la Etnologia,* vol. vi. p. 228.

[2] *Des Phénomènes Glaciaires dans le Plateau Central de la France,* etc., 1869.

The so-called conglomerate is, as Julien has shown, nothing more nor less than the *moraine profonde* of a glacier that formerly descended from Mont Dore; it is, in short, a "boulder-clay." Two irregular beds of water-worn stones are intercalated in the mass, and these separate it into three successive sheets. According to Julien, these pebble-beds testify to the action of torrential waters, and to epochs when the glacier receded and allowed water to denude and rearrange the materials of its bottom-moraine. Underneath the whole mass are found the relics of an old forest.

This glacier must have continued to occupy its ground for a long time, to judge from the thickness and the extent of its *moraine profonde*, but eventually it melted away, and by and by the rivers and streams dug deeply through it and the strata upon which it rests. A genial climate ere long supervened, and hornbeam, elm, oak, willow, ash, box, etc., clothed the land, which was tenanted by elephant (*E. meridionalis*), rhinoceros (*R. leptorhinus*), hippopotamus (*H. major*), tapir, horse, cave-bear, hyæna (*H. brevirostris*), hedgehog, deer, etc., a fauna comparable with that of the Italian and Swiss lignites.

To this genial era succeeded another cold epoch, when a glacier once more appeared in the neighbourhood of Perrier and deposited its frontal moraine above the interglacial beds which contain the remains of *Elephas meridionalis* and its congeners. Similar moraines belonging to this last period of glaciation have been traced in many different valleys throughout the great plateau of Central France, and everywhere they give evidence of having been preceded at some former time by much more extensive *mers de glace.* The older moraines had been washed down, eroded, and deeply trenched, and the strata upon which they repose had likewise been worn and profoundly furrowed by streams and rivers long before the latest glaciers had come into existence. Everything conspires to show that the genial interglacial epoch was long-continued. I may add that in certain fluviatile deposits, which M. Pomel has shown to be of the same age as the youngest moraines of Puy-de-Dome and Cantal, remains of the mammoth have been detected. Dr. Julien remarks that the more recent volcanic rocks of Central France are surmounted by " stations " of the so-called Reindeer period. No fragments of these rocks occur in the " pumiceous conglomerate," and the volcanos, therefore, must have broken out after the disappearance of the earlier and greater glaciers, and before the close of the Old Stone Age. In other words, the most recent display of volcanic activity in Central France occurred during a late interglacial epoch.

In Central France, then, we have the following succession as determined by Dr. Julien :—

1. Miocene lacustrine beds.
2. Trachytes and basalts.

3. Pliocene river-deposits with *Mastodon arvernensis, M. Borsoni*, etc.
4. Formation of great conglomerate = *moraine profonde* of extensive *mer de glace.* Two episodes of fusion.
5. General melting of ice ; deepening of valleys by aqueous erosion.
6. Interglacial beds with *Elephas meridionalis.*
7. Re-advance of glaciers ; associated freshwater beds with mammoth.

We are not without evidence in other parts of France of a similar succession of changes. M. Tardy has drawn attention to the occurrence of two distinct deposits of glacial origin in the valley of the Ain, separated from each other by a long period of time, during which great erosion of the land was effected.[1] The same geologist has also pointed out that a similar succession is met with in the valley of the Rhone, not far from Lyons.[2] Between that city and Bourg a conglomerate of glacial origin, in which now and then a striated stone may be found, underlies the old Pleistocene alluvia in which *Elephas meridionalis* occurs, and these alluvia are in turn overlaid by a more recent erratic deposit, the *moraine profonde* of the ancient Rhone glacier. The quartzite conglomerate referred to is made up of stones which show flattened surfaces such as betray their glacial origin, but it is only at rare intervals that they are found with the striæ preserved. This is no more than we might expect of an accumulation of the kind, for the stones have been rolled about in torrential waters. In one place, however, M. Tardy observed underneath the ancient interglacial alluvium an erratic deposit, the glacial character of which was evident. The ancient Rhone glacier would thus appear to have made two incursions upon the low grounds of France ; and since the Alpine glaciers of the latest cold epoch do not seem to have flowed out of Switzerland, it would follow that we have evidence so far of three successive glacial epochs in this part of Europe.

In the Black Forest, as in the Alps, we have evidence of two glacial epochs, during the first of which the glaciers advanced into the valley of the Rhine, and in all probability coalesced in part with the Alpine *mers de glace.* At the second period, however, the glaciers appear to have been confined to the valleys of the Black Forest, and did not deploy upon the low grounds beyond.[1]

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[1] *Bull. Soc. Géol. France*, t. iii., 3e Sér. p. 479.

[2] *Ibid.*, 3e Sér. t. iv. p. 285.

Many years ago M. Collomb described the occurrence of erratic blocks at lofty elevations in the Vosges, which could not have been transported into their present positions by any of the local glaciers, whose moraines now form such conspicuous objects in the bottoms of the valleys. They are met with near some of the highest summits, such as the Ballon de Guebwiller, the Ballon d'Alsace, the Drumont, and the Hoheneck, up to a height of 1000 mètres above the valley. The blocks are rounded, weathered, and of a different rock from that on which they rest. They are not striated, and have all the appearance of being extremely ancient, their surfaces being much eroded. They cannot possibly have rolled down from above; their situation on elevated cols quite excludes that supposition. Their external aspect is so different from that of the erratics of the lower regions,—from which they are separated by a zone 500 mètres in breadth, over which very few erratics are sprinkled,—that it is difficult, M. Collomb says, to admit that they can belong to the same period. If they were carried by ice the glaciers of the Vosges must then have filled the valleys to overflowing, and, escaping from the mountain-region, must have deployed upon the great plains of the Rhine, where at present no trace of their former presence has been detected.[2] But such an extension would be quite in keeping with what we know of the extraordinary development of glacial action in the Morvan and the Central Plateau of France. The action of the Rhine and its tributaries in later times might well have removed any morainic *débris* which the older glaciers of the Vosges may have left behind them in the valley of the Rhine itself.

The same geologist and M. Martins, in their interesting account of the glacier of the valley of Argelès in the Pyrenees, have mentioned similar facts which point in the same direction.[1] Erratics of granite which have come from the Pyrenees are found in considerable numbers beyond the limits of the great terminal moraines described by them. Formerly the transport of such blocks was attributed without hesitation to the action of waters, which, however, as M. Julien remarks, is out of the question. His opinion is that they are the relics of an earlier glacial epoch than that which is represented by the conspicuous lateral and terminal moraines so beautifully illustrated by MM. Collomb and Martins.

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[1] Mühlberg: *Ueber die erratischen Bildungen im Aargau*, 1869, p. 82.

[2] *Preuves de l'existence d'anciens glaciers dans les Vosges*, 1847, p. 141.

Dr. Garrigou has also recorded his discovery of traces of two different glacial epochs in the valley of Tarascon (Ariége),[2] The morainic *débris* of the earlier epoch, he says, is easily distinguished from the moraines and erratics of the later period. The former are found abundantly at levels of 800 to 900 mètres above the sea; the latter are met with in the bottom of the valley some 300 mètres below the others, and present certain features which serve to distinguish them. During the first epoch the glaciers rose above the level of the Cave of Bouichéta, even to that of Pradières, which is filled with morainic matter. It is probable, Dr. Garrigou says, that it was the water derived from the melting of the glacier which brought about the appearances visible in the Cave of Bouichéta,—at that time perhaps occasionally occupied by man. In the deeper parts of the cave are found bedded sand and clay containing articles of human handiwork, all of which might have been carried inwards by glacial waters—the objects having previously been left lying at the entrance.

Again, M. Piette tells us that the frontal moraine of the glaciers of the Pique and the Garonne, which extends between Barbazan and Saint-Bertrand-de-Comminges, reposes upon the *moraine profonde* of an older glacier, the materials of which had previously been denuded and rearranged by the action of torrential waters. At a depth of 14 mètres in this denuded and rearranged *moraine profonde* were found remains of a small ruminant, pieces of wood, and a fragment of a reindeer's horn. As to the glacial character of the *remainée* moraine there could be no doubt ; notwithstanding its treatment by torrential water, some of its stones still retained their striæ, while the rounded and *moutonnée* aspect of the contiguous mountain-slopes spoke to the former passage of a massive glacier. Again, he remarks that along the right banks of the Neste and the Garonne, between the Barthe-de-Neste and the Garonne, the hills are *moutonnées* up to a height which was certainly not attained by the glaciers of the latest glacial epoch. In short, it is clear that during some early glacial epoch, the glaciers of the Pique and the Garonne extended towards the north considerably beyond the valley of Labroquère ; that subsequently they retired, and their *moraine profonde* was denuded and rearranged by torrential action ; that afterwards they again advanced, but not to so great a distance into the low grounds.[1] The fact that the terminal moraines of the older glaciers have been obliterated, as is likewise to some extent the case with those of the Rhone, upon the plains of France, is further proof of the length of time which must have intervened between the two epochs of glaciation.[2]

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[1] *Bull. Soc. Géol. France*, 2e Sér. t. xxv. p. 141; *Mem. de l'Acad. des Sciences de Montpellier*, t. vii. p. 47.

[2] *Bull. Soc. Géol. France*, 2e Sér. t. xxiv. p. 577.

Some account has already been given of the great limestone-breccias of Gibraltar, attributed by Professor Ramsay and myself to the action of severe frost, which broke up the rock and permitted the *débris* to be carried down the slopes and over the low ground by *névé* and melting snow and rain. We found that the formation of this remarkable breccia took place at two distinct periods, separated from each other by a long period of milder conditions. The accumulation of the breccia of the first cold epoch had ceased, and the loose agglomeration of grit and large and small blocks had become cemented into an indurated mass long before the formation of the later breccias was effected. Torrents had worn gullies in the older breccia, and acidulated water percolating through crannies and fissures had gradually opened out a series of subterranean galleries and caves, which penetrated the mass in the same manner as they traversed the limestone-strata. All this took place at a time when Spain projected farther into the Mediterranean than it does now, and when the climate was mild and genial. At the period referred to Gibraltar must have appeared as a verdure-clad alp, towering above the surface of a wide expanse of undulating country that stretched south towards the coasts of Barbary, with which, indeed, it may actually have been connected. The Rock was then tenanted by the ibex in great numbers, and visited from time to time by rhinoceros, elephant, horse, boar, and deer, and by bears, wolves, hyænas, lions, leopards, lynxes, and servals, some of which may have made their lair in one or other of its numerous

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[1] *Bull. Soc. Géol. France*, 3^e Sér. t. ii. pp. 503, 507.

[2] M. Piette and one or two other French geologists, influenced apparently by Stopanni's alleged discovery that the great moraines upon the plains of Northern Italy are of Pliocene age, have assigned to the same period the oldest moraines of the Pyrenean region referred to above, as well as those of the ancient Rhone glacier which occur in the neighbourhood of Bourg and Lyons. Stopanni bases his opinion on the fact that many shells of Pliocene species occur along with glaciated stones in the morainic deposits near Como. (See "Il mare glaciale ai piedi delle Alpi," *Rivista Italiana*, August 1874 ; "Sui Raporti del Terreno glaciale col Pliocenico nei dintorni di Como," *Atti Soc. Ital. di Scienzi Natur.*, April 1875 ; *Geologia d'Italia*, Pte. 2^a, p. 131.) His views have been supported by several observers, more especially by Desor (*Le Paysage Morainique*, 1875) and Renevier (*Bull. Soc. Géol. France*, 3^e Sér. t. iv. p. 187). On the other hand, they are opposed by Rütimeyer (*Ueber Pliocen und Eisperiode auf beiden Seiten der Alpen*, p. 187) and Mayer (*Bull. Soc. Géol. France*, 3^e Sér. t. iv. p. 199),—the latter of whom especially has shown in the clearest manner that the shells referred to have been derived from a pre-existing deposit—they are the relics of

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Pliocenic strata which were ploughed into by the Pleistocene glacier, and re-arranged by water escaping from it. Having gone over the sections myself in 1878, and examined the disputed points, I came to the same conclusion as MM. Rütimeyer and Mayer. The phenomena are merely a repetition of similar appearances in the glacial deposits of our own islands and Northern Germany, where in the boulder-clay and its associated glacial sand and gravel, we occasionally detect the shells of marine and freshwater molluscs, together with fragments of wood, bone, etc.,—the relics of some pre-existing interglacial strata, which the glacial forces have broken up and commingled with other *débris.* M. Falsan had already (1875) suggested this explanation of the phenomena from from having observed in the neighbourhood of Lyons that the Pliocene contains many fossils derived from the Miocene, and that the basement-part of the Pleistocene glacial deposits (morainic detritus of the ancient Rhone glacier) shows a similar commingling of derivative shells perfectly well preserved and mixed pell-mell with boulders and striated stones; see *Bull. Soc. Géol. France,* 3e Sér. t. iii. p. 727.

caves. Now and again torrents flowing down the slopes of the mountains swept the skeletons and carcasses of these animals into gullies and underground galleries, where they gradually accumulated along with other superficial *débris*, and became in time sealed up by the action of carbonated waters. Eventually, however, a process of submergence ensued, and the land sank into the sea to the depth of 700 feet or thereabout below its present level. This movement seems to have been interrupted by longer or shorter pauses, during which the sea cut terraces or shelves upon the flanks of the Rock, shelves which have been eroded partly in limestone and partly in the old limestone-breccia (see Fig. 6, p. 217, and Fig. 10). By and by the submergence ceased, and the land was again upheaved, probably in as gradual a manner as it went down. The old sea-shelves were then partially obscured by shelly sand and gravel which had gathered over them; and from the fact that the shells, so far as can be made out, belong to species identical with those now living in the neighbouring sea, we gather that the temperature of the sea at least was at that distant date much the same as it is to-day. To what extent the land was re-elevated we cannot tell. It certainly attained a greater elevation than the present, but whether or not Spain stretched as far to the south as it

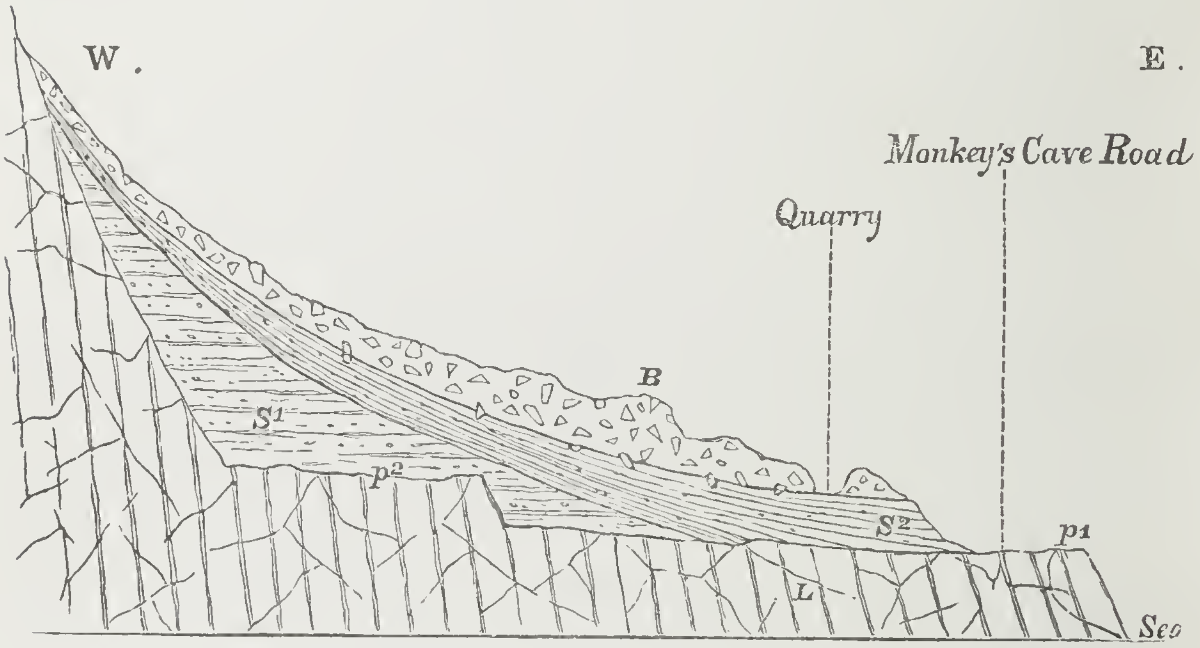

Fig. 10.—Section showing relation of Upper Breccia to Raised Beaches—Gibraltar. *L*, Limestone; S^1, Beach-deposits; S^2, Re-arranged beach-deposits; *B*, Upper breccia; p^1 p^2, Marine terraces.

did in the preceding period can only be conjectured. The sand that clothed the flanks of the Rock, acted upon by the weather, would sooner or later become "top-dressed," so to speak, and would thus form long sloping curtains or taluses, the surface of which would here and there tend to become indurated by the action of rain, dissolving the calcareous matter of the shells, and again re-depositing it between the grains of the grit and sand. By and by, however, there ensued a second cold epoch, when the limestones commenced to break up under the action of frost, while their fragments were carried down as before to the low grounds. Large blocks and smaller fragments, toppling from the lofty cliffs that face the east, fell upon the sand-slopes, here and there plunging into them where the process of superficial induration had not been sufficiently advanced to enable the sand-rock to withstand the force of the impact. Thus in time the shelly sands came to be completely buried under a thick accumulation of angular blocks and *débris*, which, having since become thoroughly indurated, presents precisely the same character as the older limestone-breccia. Underneath this newer breccia the shelly sands are often hardened into rock, and have been quarried for building purposes. There still remains a long talus of sand, however, sweeping down from the upper part of the great cliffs that overlook Catalan Bay. This sand is even yet only partially hardened, for, unlike those in the neighbourhood of the Governor's Cottage, it contains very little calcareous matter. The blocks discharged upon this slope, therefore, merely sank into it, and are now seen projecting above its surface, while many must have rolled downward to rest at the base of the Rock in regions that are now submerged. It is quite possible, however, that considerable masses of breccia may lie concealed underneath the sand, which even to the present day is blown about by the wind.

I have not had an opportunity of examining the breccias of Malta, but from the admirable descriptions given by Professor Leith Adams, I strongly incline to suspect that they show indications of climatic changes of a nature similar to those which are so clearly evinced by the great breccias of Gibraltar. The following, for example, is the summary of the section exposed by Dr. Adams in the Benghisa Gap, a narrow, steep-sided gully or trench eroded in calcareous sandstone, which he found completely filled up with sundry deposits and accumulations. The section is given in its natural sequence, from above downwards :—

1. White calcareous drift, with scattered fragments of sandstone ; shows faint traces of bedding ; six or eight feet thick ; no organic remains.
2. Layer of pebbles and red soil.
3. Layer of rounded blocks of freestone, some measuring fifteen feet in circumference, with abundant remains of Pleistocene mammals (pigmy elephants, huge freshwater turtle, gigantic dormouse, lizards, birds, etc.)
4. Rich ferruginous red loam ; not laminated ; a few pebbles and freestone-blocks intermixed.
5. Layer of gravel and rounded waterworn freestone-pebbles.
6. Large blocks of the parent rock, mixed pell-mell with red soil and silt ; occupies the bottom of the "Gap ;" mammalian remains.

Of this section Dr. Adams says—It "displays several distinct alternations of bands of large waterworn blocks and seams of loam and pebbles, representing periods of turbulence and of comparative quiescence, such as would result from violent floods or freshets pouring down a gorge. I found the elephantine remains identical in every respect with those already mentioned. Be it observed, however, that no organic remains were found in the white drift (No. 1), which, indeed, was looser in texture and more calcareous, and might in consequence have been not so preservative as the lower beds. Among the large blocks of freestone, either impacted or strewn in a heterogeneous manner, were lying seemingly entire skeletons of elephants, some of the skulls and jaws furnishing good evidence of the rough usage they had sustained by being broken and crushed flat by blocks which, with the force of impact, had cracked the others on which they impinged." He then gives some examples to show that although many of the remains were thus smashed, they had evidently not travelled far, as was indicated by the perfect state of preservation of their more fragile and delicate parts. Thus the molar of an elephant, which had been broken in two by a large block of stone, still showed the fragile coronoid process and enamel of the crown uninjured. "Entire skeletons of the dormice were found between blocks, as if their bodies had sunk into the hollows as they floated past, whilst fragments of large birds, bones, and traces of a huge freshwater turtle, and several vertebræ and skulls of lizards, as large as a chameleon, were found, in conjunction with the same land-shells mentioned elsewhere (all of living Maltese species). Several detached bones of the elephants were sun-cracked and honeycombed, as if they had been lying exposed on the surface before their deposition in the gap. Indeed, the appearances presented by this remarkable collection of organic remains seem to me to indicate that water at one time flowed down the gap, and was subject to occasional extraordinary deluges, which bore down the large blocks and whatever exuviæ came within reach; moreover, the conditions were such as we should expect when the land was undergoing a slow subsidence; thus, by diminishing the force of the stream a deposition of detritus would take place which would raise both its bed and the flood-plain around, and continue so doing as long as the subsidence continued; calms and floods decreasing or increasing the amount accordingly."[1] There is some difficulty in understanding how a slow subsidence of the land (supposing such to have taken place at the time the deposits were being accumulated) could diminish the force of the streams, unless, indeed, we are to infer that the central area or watershed and gathering-ground sank more rapidly than the lower-lying outskirts. Of this, however—extremely unlikely in itself—we have no proof. The size of the blocks, the pell-mell mixture of deposits, the state of preservation of the organic remains, the enormous masses of breccia and angular gravel—so out of proportion to the limited drainage-area in which they occur—all seem to point, as I have suggested, to extreme winters, to the action of frost and melting snow, etc. And it does seem not improbable that the indications of such conditions having alternated may point rather to secular than to mere seasonal changes—the "white drift," with its large angular blocks, representing the upper limestone-breccias of Gibraltar, and the moraines of the latest glacial epoch in the Alps and Northern Europe.[1]

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[1] *Notes of a Naturalist in the Nile Valley and Malta*, 1870, p. 191.

The facts now adduced demonstrate to us that the so-called Glacial Period was interrupted more than once by interglacial epochs of long continuance, during which the Pleistocene mammalia occupied the low grounds vacated by the glaciers and the great *mer de glace;* elephants, rhinoceroses, and hippopotamuses living then as far north as England and North Germany. Palæolithic man, as we now know, was also an interglacial resident in England and Switzerland, and doubtless of many other parts of Europe at the same time. The climate of those interglacial epochs was certainly not less genial than that of the present; indeed, if we may judge from the assemblages of plants and animals which occur in the Swiss, Italian, French, and German deposits, it would seem to have been remarkably equable, the seasons not being so strongly contrasted as they are now. In a word, the climatic conditions appear to have been of the same character as those during which the tufas and travertines of Tuscany, France, and Germany were accumulated. Thus just as we found reason for concluding that the Pleistocene river- and cave-deposits, with their arctic and alpine fauna, must have been contemporaneous with the former much greater extension of snow-fields and glaciers in Europe, so does the conviction grow upon us that the laurels and fig-trees of Northern France, and the hippopotamuses and elephants so generally distributed through the Pleistocene beds of North-western Europe, must be synchronous with the flora and fauna of interglacial ages.

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[1] Coarse limestone-breccias are well known to occur in various places throughout the Mediterranean region, the origin of which has never been satisfactorily accounted for. They are not forming now, but are being furrowed and worn away, just like the limestones upon or near to which they repose. That many of them date back to Pleistocene times is not disputed; what more likely, then, than hat they are the southern representatives of our glacial deposits?

CHAPTER XIV.

CLIMATIC AND GEOGRAPHICAL CONDITIONS OF PLEISTOCENE PERIOD—SUMMARY.

Climatic and geographical conditions of Europe during Pliocene times—Gradual change of climate and commencement of Glacial Period—Modification of fauna and flora in glacial times—Geographical conditions in Pleistocene Age—Land-connection between Europe and Africa—Continental condition of British area—Dry land in the English Channel—Human relics in Pliocene strata—Cut bones in Italian Pliocene—Human relics in Miocene strata—Geographical conditions in Europe at the beginning of the last interglacial epoch—Migrations of plants and animals—Character of interglacial climate—Geographical conditions at climax of last interglacial epoch—Gradual deterioration of climate—Geographical conditions towards close of last interglacial and beginning of last glacial epoch—Last glacial epoch—Migrations of plants and animals—Final disappearance of great glaciers, etc.—Distribution of interglacial deposits—Interglacial age of Palæolithic man and mammalia of southern group.

Before we proceed to inquire into the physical conditions which obtained in Postglacial and Neolithic times, it may be well first to glance back over the ground we have traversed, for we have now reached a point from which much that may have appeared confused and obscure on the way, will no longer, I hope, offer any real difficulty. We commenced our investigations, it may be remembered, by passing in review the fauna and flora of the Pleistocene Period, and thereafter we inquired into the character and origin of the deposits in which those plant- and animal-remains have been preserved. We then discussed the subject of glacial and interglacial epochs, with the result of discovering that the cave- and river-accumulations, which we had hitherto always spoken of as Pleistocene, were really synchronous with our glacial and interglacial deposits. They were all laid down, in fact, during one and the same prolonged period; a period characterised by several extraordinary changes of climate, and certain considerable modifications in the outline of sea and land. When therefore I use the term "Pleistocene Period" in future, it will be understood as comprehending all the great cycle of changes embraced in what is known as the Ice Age or Glacial Period.

In times anterior to the Pleistocene Period, that is to say during the Pliocene Age, Europe was occupied by a flora and fauna which were destined to become profoundly modified before the advent of the first glacial epoch. The rich and abundant vegetation of the Miocene was still represented by many identical or nearly allied species, although the palms and other characteristic forms had disappeared. It was the same with the fauna. Many of the most typical Miocene families had vanished, but the mastodon survived down to nearly the close of the Pliocene Period. The climate, we can safely affirm, was more genial than the present, and appears to have been extremely equable. This is clearly evinced by the character of the Pliocene flora. Not only was this richer in genera than that of our own day, but some of those genera were richer also in species. The flora was likewise singularly uniform, according to Count Saporta, who remarks that the environs of Bologna, Tuscany, the district round Lyons, and Cantal, were occupied by the same species. The great forests, he says, seem to have covered vast areas, occupying the plains, the borders of rivers, and extending up the valleys even to the crests of the mountains, without much change of character. The ivy, the platanus, the liquidambar, various maples, and many walnut trees, elms, hornbeams, laurels, sassafras, and others, ranged from Central Italy to the heart of France. It was an abundant vegetation, composed for the most part of great trees, some of which were Miocene plants, destined soon to become extinct; some again were special forms belonging to genera which are now exotic; others were species which have survived to the present in more southern and eastern regions, while yet others are still represented in Europe by identical or very closely allied species. Thus, according to Saporta, the flora of the Pliocene is connected both with the past and the present plant-life of Europe, while, at the same time, it has relations with the floras of distant southern and eastern regions —regions now separated by wide stretches of sea—America, the Canaries, Eastern Asia, Japan, and China.[1]

During the same period the shores of North-western Europe were washed by genial waters, in which lived many species of molluscs, which must now be sought for in the seas of more southern latitudes. All the palæontological evidence, in short, implies an equable and uniform climate which permitted the intimate association in our continent of many types, both animal and vegetable, now no longer able to co-exist at similar elevations, or in one and the same latitude.

The European area during the Pliocene Period appears at one time to have been more extensive than it is at present, and at another epoch to have experienced no inconsiderable amount of submergence. The Adriatic and the Mediterranean rose high upon the slopes of the Apennines—the valley of the Po forming then a great arm of the sea which penetrated the mountain-valleys of the Alps. The valley of the Arno, likewise, was under water, so also were the lower reaches of the Rhone and extensive tracts in the maritime district of South-western France. In like manner Sicily was to some extent submerged, and the sea overflowed wide areas in Belgium and the low-lying parts of East Anglia.

It is in the ancient deserted sea-bed of the Pliocene that we detect that gradual deterioration of climate and approach of colder conditions, which eventually culminated in the first glacial epoch. In the older marine deposits of the English Pliocene southern forms are present in great force, but they gradually become less numerous as we follow them into the upper or overlying strata; while at the same time immigrants from the north make their appearance and continue to increase in number as we approach the more recent accumulations of the Pliocene sea. Now and again, too, we come upon isolated large stones which have in all probability been dropped from floating - ice. Northern forms, such as the shallow - water species, *Mya truncata, Saxicava norvegica*, and *Buccinum undatum*, made their way at this time even as far south as Sicily. We may be sure that if such changes were taking place in the water, the land could hardly escape similar experiences. The southern forms of plants and animals would disappear, some retiring to more genial latitudes, others becoming extinct, and as they vanished their vacant places would be seized upon by the hardier tribes advancing from the north. That not a few animals and plants became extinct at this time we have every reason to believe. Amongst the former were mastodon, hipparion, and many kinds of deer. The splendid flora too suffered greatly, many of the forms dying out altogether, while of those that survived to later times, the greater number were more or less modified. The approach of the first glacial epoch was heralded by the appearance of many animals characteristic of the Pleistocene Period. Their appearance, indeed, marks the close of the Pliocene. They were commingled with certain Pliocene species, some of which struggled on into interglacial times. Thus England in preglacial ages was tenanted by elephants, rhinoceroses, hippopotamus, and machairodus, by bears, Irish deer, and many other cervidæ, by urus, wild-boar, wolf, fox, beaver, and so forth. Of these, some did not survive Pleistocene times, others outlived that period to become extinct in the Neolithic Age, while yet others endured all the changes and chances of the Glacial Period, and still form part of the European fauna.

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[1] *Compt Rend. Assoc. pour l'Avance. des Sciences*, 1873, p. 461 ; see also *Bull. Soc. Géol France*, 3^{e} Sér. t. i. p. 212.

Underneath the oldest known boulder-clay—that of Cromer in Norfolk—occur certain fluvio-marine deposits, the plant-remains in which bespeak the kind of climate that characterised England at the commencement of the first glacial epoch. That flora embraced Scots fir, spruce fir, yew, alder, oak, birch, white and yellow water-lilies, bog-bean, common sloe, etc.—indicating a climate perhaps a little colder, but not essentially differing from that of Norfolk at present. But as the plants are traced upwards through the strata they were found by Mr. Nathorst to become more and more stunted and meagre, until in a bed immediately underlying the boulder-clay he came upon the Arctic willow (*Salix polaris*), and a moss (*Hypnum turgescens*) now confined in temperate latitudes to the highest alps.[1] The latter grows in Herjedalen on the Dovrefield, in the north of Scandinavia, in Bear Island, Spitzbergen, and Greenland. Thus we learn how the arctic and alpine flora, driven southwards by the encroachment of the great northern *mer de glace*, at last came to occupy the low grounds of temperate Europe.

I shall not attempt here to summarise the history, so far as that has been ascertained, of each particular glacial and interglacial epoch, but after some general remarks will proceed to describe the climatic and geographical changes which characterised our continent towards the close of the Pleistocene, that is to say during the last interglacial and glacial epochs. That the successive invasions of Northern Europe by vast *mers de glace*, and the repeated appearance, in the hilly regions of more southern latitudes, of perennial snow-fields, must have profoundly modified the flora and fauna cannot be doubted. It is highly probable also that the presence of the Mediterranean, by presenting a more or less insurmountable barrier to the south, and thus cutting off the retreat of many species, may have contributed largely to the extinction of Pliocene animals and plants, which but for that barrier might have crossed into Africa, and found there conditions suited to their needs. It is for this reason that the European flora of to-day differs so much more from that of Pliocene and Miocene times, than the flora of North America does from the plant-life of those periods. In the latter continent there existed a continuous passage to the south, across which plants and animals alike could make good their retreat. But in Europe the Mediterranean, now larger and now smaller, appears to have endured all through the Pliocene and Pleistocene Periods. Ever and anon, it is true, land-connections between Europe and Africa made their appearance, and so afforded bridges by which the species came and went with the alternation of climatic conditions, but many nevertheless must have died out upon the northern shores of the Mediterranean.

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[1] *Antiquity of Man*, p. 261 ; *Öfversigt af Kongl. Vet.-Akad. Förh.*, 1873, p. 18.

We have seen that a number of characteristic Pleistocene animals had made their appearance in England at the close of the Pliocene Period, or shortly before the advent of the earliest recognised glacial epoch of Pleistocene times. They were associated with several Pliocene forms, such as *Hippopotamus amphibius, Elephas meridionalis, Machairodus latidens, Rhinoceros etruscus, R. megarhinus, Ursus arvernensis, Cervus dicranios,* and *C. polignacus.* Of these, one, the hippopotamus, is still living, while others do not appear to have survived in North-western Europe the first glacial epoch. The southern elephant and the megarhine rhinoceros, however, struggled on into interglacial times, when the former occupied the valley of the Rhone, Central France, and Northern Italy, and the latter ranged from Southern Europe into England. The sabre-toothed tiger also would seem to have persisted well on into the Pleistocene Period. Of the other animals that come into view for the first time in the Preglacial deposits of Cromer, many appear and re-appear in successive interglacial deposits; but we note as we advance towards the later stages of the Pleistocene that some of them become rare, while others vanish altogether. The recurrent glacial epochs seem to have told severely upon many of the herbivorous animals. The only two pachyderms that have survived are the hippopotamus already mentioned and the African elephant. During each successive glacial epoch those species which could only exist under a mild climate would be forced to the extreme south of Europe, where, confined within ever-narrowing limits, they would gradually die out. Only the more robust types, such as stag, megaceros, urus, bison, horse, mammoth, woolly rhinoceros—species capable of enduring some severity of cold—

would live on. The carnivores, however, might be expected to thrive wherever their food-supply was sufficiently abundant, they would prey alike on the denizens of the southern regions and the occupants of less temperate latitudes. Most of them, therefore, were enabled to endure all the climatic vicissitudes of the Glacial Period, and many are recognised as still living species.

Now, it is quite evident that the presence in Europe of such animals as the lion, the elephant, the hippopotamus, and others, speaks to a former union between this continent and Africa. And again, the occurrence of the musk-sheep, the pika, and other boreal species, either now or in Pleistocene times living in Europe, proves in like manner the former existence of a land-connection between Europe and America. That such connections have obtained within comparatively recent times, geologically speaking, might easily be inferred from the fact that many living species of plants and animals are common to the northern regions of North America, Asia, and Europe, and the same holds true as regards South Europe and North Africa. In like manner we know that the British Islands must have been united to themselves and the Continent before they could have received their present fauna and flora.

There are many good reasons for believing that at least two land-passages existed between Europe and Africa. One of these extended south from Tarifa Point in Spain to the opposite coast of Barbary, and the other stretched from South Italy, by way of Sicily, to the present shores of Tunis. A comparatively small elevation of the land would suffice to restore the configuration of Southern Europe that obtained in Pleistocene times. A rise of only 1000 feet or so would provide a land-passage from Barbary into Spain, while an elevation of 1200 feet would join Malta to Italy and Tunis. There can be little doubt that it was by one or other of these routes, or by both, that southern forms, like the elephant and hippopotamus, crossed and re-crossed during alternating climatic conditions. Now, a glance at the Admiralty's charts of the Mediterranean will show that an elevation sufficient to unite the two continents would join Corsica and Sardinia and Malta to the mainland. If the movement of elevation were continued east as far as the Archipelago it would also effect very considerable modifications in that quarter, uniting many of the small islands to themselves and the adjacent shores of Greece and Asia Minor. It is quite possible, indeed, that the old shore-line of the Mediterranean may now be submerged to a considerably greater depth than 1200 feet, and that the area of land may have been more extensive during some interglacial epochs than would now be brought about by an uniform elevation just sufficient to connect the continents of Europe and Africa by the two land-passages referred to. There are no good grounds, however, for supposing that this was the case. All that we can be quite certain of is simply this, that one or more land-connections formerly existed. A tooth of the pigmy hippopotamus has been discovered in Crete, from which Professor Boyd Dawkins has inferred that this island joined on to the Peloponnese, where remains of the same animal have been found. And as the depth of the intervening sea is "400 to 500 fathoms,"[1] he concludes that the whole Mediterranean area has subsided some 3000 feet since the Palæolithic Period; or, in other words, that Southern Europe and the opposite coasts of Africa stood, during the Old Stone Age, 3000 feet or so higher than they do now. But we are not entitled to assume that the subsidence has been uniform over the whole basin of the Mediterranean. On the contrary, there are many considerations that would lead us to an opposite conclusion. It may quite well be that the greater depth between Greece and Crete is simply due to that region having been more deeply submerged than the areas farther to the west; for the configuration of the sea-bottom in the Archipelago and the neighbourhood of Crete is indicative of very considerable local depressions—the result, doubtless, of those movements that so frequently characterise a region which, like that under review, is subject to volcanic action. Thus, even if the proof were stronger than it is that Crete was joined directly to Greece at the same time that land-passages extended from Barbary to Spain, and from Tunis to Sicily and Italy, yet it would be very unsafe to measure the general loss of land experienced in the Mediterranean area since that time by the present depth of the sea that lies between the island of Crete and the Peloponnese.

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[1] *Cave-hunting*, p. 382. According to the charts a considerably less degree of elevation than 500 fathoms would unite Greece to Crete; and the connection of that island with the mainland need not have been direct by way of Cerigotto and Cerigo. See *Geological Magazine*, vol. x. p. 49.

Turning our attention for a little to the north-western regions of Europe, we find that there has been a very considerable loss of land in that direction since Palæolithic times. The evidence for this is not derived entirely from the occurrence in British Palæolithic deposits of the remains of animals that were formerly common to the area of our islands and the Continent; but, as we shall see presently, equally convincing proofs of the disappearance of a wide land-area are supplied by quite another line of inquiry. So far as the evidence of the old mammalia goes, we need only to admit that the British Islands were united to themselves and the Continent, and an elevation of less than 400 feet would suffice to restore such a connection; for although the Straits of Dover are not more than 30 fathoms deep, yet the sea between Wicklow and Pembroke is not less than 50 or 55 fathoms in depth. But an elevation of only 400 feet would yet lay dry a large part of the German Ocean and the English Channel, and the remarkable configuration of the sea-bottom leads us to believe that the present 100-fathom line probably marks out for us the limits reached by the European coast in Palæolithic times.[1] The soundings in the British seas and off the west coast of the Continent prove the existence of a broad submarine plateau, the general depth of which from the surface is under 600 feet. (See Plate E.) This plateau extends beyond the shores of Ireland, the Outer Hebrides, and the Orkney and Shetland Islands, so that an elevation of only 600 feet would add considerably to the size of Europe. Immediately beyond the margin of the plateau, however, the sea deepens more or less suddenly to such an extent that an additional elevation of 2000 feet would cause the west coast of Europe to advance very little farther into the Atlantic. But the same amount of upheaval would lay bare much of the sea-bottom in the extreme north, so as to connect Novaia Zemlia with Norway, while at the same time Iceland and the Færöe Islands would unite to form one large island. Whether the Europe of interglacial times extended so far to the north we cannot positively assert; but we have, at all events, very good grounds for believing that much of the sea-bottom in our own latitudes, which now lies under a depth of 100 fathoms, was dry land during some part of the Pleistocene Period, so that in those days neither the North Sea nor the English Channel had any existence, and the Gulf of Bothnia and the Baltic may have been freshwater seas. But if we have proof of a former wider extent of land, we have, on the other hand, no less good evidence to show that at certain stages in the Pleistocene Period large areas, both in the north and south of Europe, were submerged. The occurrence of one and the same terrestrial fauna in the Pleistocene deposits of England and the Continent bears witness to the former union of Britain with the latter—the appearance of existing species of marine mollusca at high levels in Scandinavia and our own islands testifies just as certainly to recent submergence and re-elevation of the land.

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[1] Mr. Godwin-Austen (*Quart. Journ. Geol. Soc.*, vol. vi. p. 69) has shown good grounds for believing that the old coast-line of Britain may have extended as far out to sea as the present 200-fathom line, and with him Professor Prestwich is inclined to agree (*Phil. Trans.*, Part II., 1879, p. 690). I do not dispute their conclusions, and am quite prepared to agree with them that the ancient coast-line may now be nearer 200 than 100 fathoms under water. But as all the evidence referred to in the text is quite explicable on the assumption of a former elevation of 100 fathoms, I prefer the more limited estimate. For a former elevation to that extent, at least, the proofs are as complete as we could expect.

But it is not from the occurrence of those organic remains alone that changes in the geographical outline of Europe are inferred to have taken place. The present position of the ancient

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Any greater degree of upheaval and subsequent depression is more or less problematical, although, as I have said, the evidence adduced by Mr. Godwin-Austen is not without its weight. See further upon this subject Chapter XXI.

river-deposits of Palæolithic times proves, in the most impressive manner, that at the date of their formation the shores of England extended considerably farther out to sea than they now do. Let us take an example. From the observations of the Rev. W. Fox, Mr. T. Codrington, and Dr. Evans, it has been ascertained that during the occupation of Southern England by Palæolithic man the Isle of Wight formed part of the mainland—connected to it by a range of chalk-heights extending west from the Needles to what is now the coast of Dorsetshire. At that period the hollows presently occupied by the sea, and called the Solent and Southampton Water, were valleys which collected the tribute of many streams that now find their way directly to the sea. England was then, in all probability, joined to the Continent, and the ancient river of the Solent may have merged its waters with those of the Seine upon what is now the bed of the English Channel. I do not mean to say that the direct evidence furnished by the gravels of Hampshire and the neighbouring districts actually proves that such was the case. All that we are entitled to infer from that evidence is simply this, that the Solent is an old land-valley. At what particular point the ancient river discharged into the sea, or whether or not it really joined the Seine, can only be conjectured. We must remember, however, that the Hampshire gravels are but a small portion of the evidence, to which we have to add that of the fauna and flora, enough of itself, as we have found, to prove that England, during some stages at least of the Pleistocene Period, formed part and parcel of the Continent. To restore such a connection only a small amount of elevation would be necessary, for the Straits of Dover are not deeper than 30 fathoms or thereabout, while the depth between the Isle of Wight and the opposite coast of France hardly exceeds 40 fathoms. Direct evidence, then, in favour of the ancient Solent river having been an affluent of the Seine must, in the nature of the case, be wanting. We know, however, that the bottoms of certain old valleys in Scotland, which are quite choked up with accumulations of Pleistocene age, are as much as 200 or even 260 feet below the sea-level, and this, of course, indicates a former greater amount of elevation. Similar buried river-channels occur in the east of England, and doubtless many exist that we do not know of. Could all the deposits of Pleistocene age be taken out of the valley of the Thames so as to lay bare the older Tertiary and Cretaceous strata, we should find that the sea would enter far into the country and cover a broad area. No one, indeed, can study the distribution of the old Pleistocene "river-drifts" without perceiving that the valleys in which they lie must at one time have extended much farther into regions that are now submerged. There is nothing, therefore, abnormal in the fact that the hollow occupied by the Solent was, in Palæolithic times, a land-valley. By referring to the Admiralty's charts we find that the average depth of the Solent is not more than 54 feet, but there are some places where it is as much as 70 and 120 feet. In Southampton Water depths of 70 and 90 feet occur. If the greatest depths of the Solent be not due to the action of currents eroding the sea-bottom (which is unlikely), then it would follow that the ancient submerged valley might well have continued eastward to a point not far removed from the present 30-fathom line. Of course in all this there is an element of uncertainty, and I only state it to show that there is nothing unreasonable or extravagant in the view that the old river of the Solent may have been a tributary of the Seine in Palæolithic times. But that Palæolithic man saw the Isle of Wight as part of the mainland there cannot be any reasonable doubt. He and his congeners may have wandered upon the slopes of the high chalk downs that once extended between the Needles and the Dorset coast, but have long since crumbled into the sea ; and they may have followed the ancient river of the Solent down through what is now Southampton Water to the shores of the sea somewhere opposite Selsea. But if, as we have many reasons for believing was the case, our land stood in those days several hundred feet higher, then man may have hunted the mammoth and the reindeer over the whole wide area now covered by the waters of the English Channel.[1]

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[1] For their knowledge of the geographical conditions which obtained in

Although relics or remains of Palæolithic man have never yet been discovered in deposits which can be demonstrated to be of preglacial age, yet geologists have long been of opinion that he arrived in our latitude as early at least as the old extinct mammals which were his congeners all through the Pleistocene Period. That he lived in England during the interglacial epochs cannot be any longer doubted, and since his relics are met with not only in the oldest Pleistocene river-alluvia, but also in the lowest accumulations in our caves, some of which are almost certainly of preglacial age, the general opinion that he was most probably in occupation of England before the advent of the first glacial epoch seems, in the highest degree, likely to be true. Some, indeed, will have it that he entered Europe in Pliocene times, which is, *à priori*, not improbable.

The cut and scratched bones of *Elephas meridionalis, Rhinoceros leptorhinus, Hippopotamus major,* and other animals, discovered in 1863 by M. Desnoyers, in the upper beds of the Pliocene of St. Prest, have been attributed by him and many geologists to man's hand. By others the evidence has been thought insufficient. More recently, however, M. l'Abbé Bourgeois, an enthusiastic archæologist, has discovered, in the same deposits, worked flints, about the human origin of which there seems to be no doubt. These gravel-beds, however, although they are usually considered to belong to the Pliocene, are, by some competent authorities, held to be rather of early Pleistocene age; to be equivalent, in short, to the preglacial deposits which underlie the boulder-clay of Cromer. Indeed it is not impossible that they may even be of interglacial age, for their mammalian remains agree closely with those of the interglacial strata of Mont Perrier.

Professor Capellini has described the discovery in Pliocene strata of the bones of a whale (*Balænotus*), which are marked

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the Channel-area during Pleistocene times geologists are indebted, in large measure, to Mr. Godwin-Austen, whose numerous papers, published in the *Quarterly Journal of the Geological Society*, are full of valuable information, and marked by a spirit of philosophical induction, and a breadth of view, which every student of Pleistocene geology must gratefully acknowledge and appreciate.

with incisions and cuts such as only a sharp instrument could have produced. These interesting remains were disinterred from the Pliocene of Poggiarone, in the valley of the Fine; and from the position in which they were found, and the character of the deposits in which they were embedded, it appeared evident that the whale had been stranded in shallow water upon the shores of one of the islands in the Pliocene archipelago of Central Italy. The manner in which the bones have been cut certainly seems suggestive of human handiwork. The incisions are entirely confined to the outside faces of the rib bones, and to the apophyses of the vertebræ; while the internal surfaces are invariably intact. Professor Capellini informs me that the shoulder-blade of a little cetacean recently received by him is marked on one side only with incisions forming nearly a circle. According to him and others these appearances could only be produced by the hand of man, and from the position occupied by the *débris* of the skeleton the Bologna professor has convinced himself that the animal was stranded when discovered by man, who, by means of flint knives or other sharp instruments, hacked away such morsels as he wished. It must have been lying on its left side when it was operated upon, for it is upon the bones of the right side only that the sharp incisions and cuts occur. Similar cut bones of cetaceans have been discovered in the Pliocene of other localities, from which it is inferred that whales, both large and small, frequently ran aground upon the margin of the old Pliocene sea, just as they do now upon our present shores. These discoveries appear to have been made invariably in beach-deposits, close to the margin of the ancient sea—the rocks forming which are frequently bored by lithophagi, as, for example, near Santa Luce, in the valley of the Fine, which must have been at that time a fiord.[1] The cut bones have been examined by many competent osteologists, who agree with Capellini that the markings are man's handiwork, and who have testified to the authenticity of the relics, observing that the cuts are coated with an incrustation of the same mineral matter which clings to the bones.[1] If their conclusion be true, then the only question that can arise is the antiquity of the beds in which the bones occur. Are these of Pliocene age? Of this the Italian geologists, who must be the most capable judges, entertain no doubt. We may anticipate, therefore, the future discovery of human implements, and probably of human remains also, in Pliocene strata.[2]

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[1] L'Uomo pliocenico in Toscana, *Atti della Reale Accademia dei Lincei*, Ser. 2, t. iii.

Of a yet more extreme antiquity are the reputed implements discovered by M. l'Abbé Bourgeois, at Thenay, in strata, the Miocene age of which is not disputed. According to the Abbé these implements betray all the evidence of having been fashioned and used by man. He draws attention to the symmetrical form of the flakings, to the retouches, to the bulbs of percussion (which, however, are rare), to the traces of blows and use, to the marks of fire—some of the stones having been used probably as "pot-boilers"—and lastly, to the multiplied production of certain well-known forms.[3] M. Carlos Ribeiro, of the Geological Survey of Portugal, had already noted similar discoveries of worked flints and quartzites in the Pliocene and Miocene of the Tagus,[4] a collection of which he exhibited at the Anthropological Congress in Paris in 1879. A worked flint has also been recorded from the Miocene of Aurillac (Auvergne) by M. Tardy, and a cut rib of the Miocene species, *Halitherium fossile*, has been found by M. Delaunay at Pouancé (Maine et Loire). But there is still much difference of opinion as to the probability of man having existed in Miocene times. At the Congress of archæologists and anthropologists, held in Brussels (1872), opinion seemed to be equally divided for and against the human origin of the Miocene "flints" which M. l'Abbé Bourgeois submitted for examination. On the one side were MM. Worsaae, d'Omalius, Capellini, Mortillet, and other experts, who agreed with the Abbé; on the other side were MM. Steenstrup, Virchow, Fraas, and Desor, who opposed his views; while some again, like M. Quatrefages, reserved their judgment, and were content to wait for additional evidence. "Since then," says M. Quatrefages, "fresh specimens discovered by M. l'Abbé Bourgeois have removed my last doubts. A small knife or scraper, among others, which shows a fine regular finish, can, in my opinion, only have been shaped by man. Nevertheless, I do not blame those of my colleagues who deny, or still doubt. In such a matter there is no very great urgency, and, doubtless, the existence of Miocene man will be proved, as that of Glacial and Pliocene man has been, by facts."[1] Some palæontologists, in rejecting the evidence produced by the Abbé, appear to have been influenced by the consideration that all the mammalia of Miocene times have disappeared from the living world, and that, therefore, it is very unlikely that man, related to them so closely in organisation, could have survived the action of those causes which resulted in the extinction of all the terrestrial mammals with which he is inferred to have co-existed. To which Quatrefages has pertinently replied that although he recognises the force of such objections, he yet must take into account human intelligence, which some palæontologists seem to forget. It is evidently owing to this intelligence, he remarks, that the man of the Pliocene Age was able to survive two great geological periods. "He protected himself against cold by fire, and so survived till the return of a more genial temperature. Is it not possible, therefore, to imagine that man of an earlier period should have found in his industry the necessary resources for struggling against the conditions which the transition from the later Secondary to the earlier Tertiary must have imposed upon him?" There is unquestionably much force in what M. Quatrefages says; nevertheless, most geologists will agree with him that the question of man's Miocene age still remains to be demonstrated by unequivocal evidence. At present, all that we can safely say is that man was probably living in Europe near the close of the Pliocene Period, and that he was certainly an occupant of our continent during glacial and interglacial times. That being so, let us try to picture to ourselves the climatic and geographical conditions of which he must have been a witness towards the end of the Pleistocene Period.

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[1] Objections, however, have been urged against Capellini's views. Dr. Evans, for example, has suggested that the incisions might have been made by the teeth of fishes (*Compt. Rend. Congrès Intern. d'Anthrop. et d'Archéol. Préh.*, 1876, p. 46). See also Stefani; *Atti Accad. dei Lincei*, Ser. 3, t. ii., 1878. If the incisions had been made either by teeth, claws, or other natural armature of animals, one might well ask, with Capellini, why similar cuttings should not be visible on most of the bones found in the same bed?

[2] Professor Boyd Dawkins, referring to the fact that flint flakes and fragments of rude pottery have been met with at the place where the incised bones were found, has concluded that the latter cannot be of the age assigned to them by Professor Capellini. "Pottery," he remarks, "was unknown in Europe in the Pleistocene, and therefore is unlikely to have been known in the Pleiocene age" (*Early Man in Britain*, p. 92). This objection, however, is based upon a complete misapprehension. Professor Capellini tells me that the flint flakes and rude pottery were found lying at the surface, and were never for a moment imagined by him to belong to the same age as the cut bones.

[3] *Compte Rendu du Congrès International d'Anthrop. et d'Archéol. Préhist.*, 1873, p. 81.

[4] *Descripçao do Terreno Quaternario das Bacias dos Rios Tejo e Sado*, 1866.

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[1] *The Human Species*, 2d edit., p. 151.

Let us suppose, then, that the penultimate glacial epoch had come, and was again passing away to give place to the last interglacial era. The great northern ice-sheet which had overflowed the plains of Northern Germany had melted away, the British area had likewise become divested of its glacial covering, and in the mountain-valleys of the Alps and other elevated regions in Central and Southern Europe the glaciers were dwindling to moderate proportions. The northern fauna and flora at the same time were gradually retreating towards alpine heights and boreal regions, while the low grounds of Central and North-western Europe, slowly acquiring a temperate climate, were being reclothed and repeopled by those tribes and families of plants and animals which were now returning to their former homes. The reindeer, the musk-sheep, and their congeners had forsaken the plains of France, and had retreated northwards from Germany, Belgium, and England; the mammoth and the temperate group of mammalia—urus, bison, Irish deer, stag, roe, horse, saiga, wild-cat, wolf, bear, lion, hyæna, and their humbler associates—beaver, hare, rabbit, stoat, weasel, etc.—were now the common forms to be seen in Central and North-western Europe. When the meridian of the last interglacial epoch was attained, a climate approximating to that of Pliocene times characterised our continent. More humid than the present, it was at the same time much more equable. Severe winters in our latitude were probably unknown. A dense forest-vegetation covered all the low grounds, and doubtless invaded the valleys and hill-slopes of mountain-regions. Plants which cannot now co-exist in one and the same locality were then widely diffused over vast regions. From Central Italy up to Switzerland and Würtemberg, and from the shores of the Gulf of Lyons as far north as Paris, an uniform flora prevailed. The Canary laurel flourished at once on the banks of the Seine and the borders of the Mediterranean. In the neighbourhood of Paris it was associated in one and the same place with the fig-tree, the judas-tree, the sycamore, and the ash. In the extreme south of France it grew side by side with pines which have now retreated to the mountains. The conditions were the same in Italy. There laurels, magnolias, walnuts, fig-tree, judas-tree, beech, evergreen oak, laurustinus, manna-ash, and many others, were commingled—all testifying to the humidity and extreme equableness of the climate. Of the contemporaneous flora of England and the north we know but little—only a very few traces of it have been met with. In Scotland, oaks, pines, alder, birch, and ash were among the trees, from which it may be inferred that the climate of our regions was not less genial then than it is to-day. We can hardly suppose it possible, however, that the delightful climatic conditions which obtained from the Mediterranean region up to Central Europe did not also extend to our own latitudes. Our winters must at that time have been very much milder, although doubtless our more northerly position would tell upon our flora, and cause it to differ as much from that of Middle Europe as the latter did then from the flora of Southern France and Tuscany.

The British Islands were united to themselves and the Continent and one or more broad rivers, carrying the tribute of the Elbe, the Weser, and the Rhine, the Thames and other streams of East Britain, flowed down through the vast plains now covered by the North Sea to fall into the Northern Ocean. The western coasts of Europe advanced for many miles into the Atlantic. The Seine with its English tributaries poured through what is now the Channel, to meet the ocean at a point probably not less than 100 miles beyond Ouessant Island. From Argyle in Scotland there extended a deep freshwater lake which passed south into the basin of the Irish Sea, and sent its surplus water in a broad stream through the hollow of St. George's Channel, then a valley in that wide expanse of low ground which stretched south-east from the south of Ireland to the borders of the French Landes. With such conditions obtaining in the North Sea and Western Europe, it is likely that the Baltic existed as a freshwater lake. In the Mediterranean region the contrast between the past and the present was not less striking. A bridge of land connected Italy and Malta through Sicily to the coasts of Tunis, and Spain in like manner was joined to Barbary. Corsica and Sardinia, united to Italy, formed a peninsula; and the Balearic Isles similarly would seem to have constituted a portion of the Spanish mainland. Dry land extended over the greater part of the Adriatic and the Grecian archipelago; in a word, the shores of the Mediterranean generally extended farther out to sea than now.

Such were the geographical conditions of Europe when the southern mammals—the hippopotamus, the elephant, the rhinoceros, and their associates—advanced northward to commingle with the denizens of temperate latitudes. Elephants and rhinoceroses roamed over the same feeding-grounds as Irish deer, oxen, horses, and bisons; hippopotamuses frequented the rivers that flowed through lands where these and other animals of southern and temperate habitats abounded. Southern and temperate forms, in fact, ranged together from the Mediterranean region up to the north of England; the mammoth, the horse, the Irish deer, and probably many others, lived in Scotland. Many carnivores, at the same time, occupied the forests that covered the land, and preyed upon temperate and southern animals alike.

Lions, hyænas, and bears haunted the caves—and with all these creatures Palæolithic man was contemporaneous. The land- and freshwater-shells showed a similar remarkable commingling of species—all the evidence, in short, conspires to assure us that the climate was singularly equable. If laurels, fig-trees, and judas-trees grew side by side in Northern France with the sycamore and the ash, and in low-lying countries on the borders of the Mediterranean with pines, oaks, beeches, poplars, and elms, so also were elephants, rhinoceroses, and hippopotamuses, horses, oxen, and deer, hares and rabbits, wolves, foxes, lions, and hyænas, joint-occupants of the same regions. The humidity of the climate is evinced by the character of the vegetation no less than by the peculiar distribution of the mollusca. And the great breadth and depth attained by the streams and rivers is further testimony in the same direction.

By and by the climate began to change, and the succession which I have briefly described above was reversed. The winters became colder—perhaps, too, the rainfall increased. The tender southern species of plants now commenced to retreat from Middle Europe and to creep farther and farther south, and a like migration of the fauna ensued. At the same time the British area began to subside. The North Sea once more made its appearance; the Channel again came between England and the Continent; slowly the land sank into the water—the submergence reaching in Wales and Ireland to as much as 1200 to 1300 feet below the present sea-level, and in Scotland probably to a similar or even a greater depth, although of that we have no direct evidence. While this downward movement was in progress, the deterioration of the climate continued, and northern and boreal molluscs made their appearance in our seas and increased in numbers as time went on. Whether the Scandinavian peninsula was submerged to the same extent we cannot tell—if it was, all proofs of that change (unless my suggestion as to the interglacial age of the ancient rock beach-lines of Norway should prove to be well founded) must have been removed during the immediately succeeding glacial epoch. The

Channel-area—the borders of Northern France and Southern England—do not appear to have subsided more than a few fathoms below their present level. But the depression increased towards the north or north-west, and seems to have reached its maximum in Wales, the north-west of England, and in Ireland. After that maximum was attained a movement in the opposite direction followed—the land began to emerge and the sea to retire, and still the cold continued to increase. About this time we know that the low grounds of Prussia were submerged by a sea in which *Leda* (*Yoldia*) *arctica* abounded—a fact which may lead us to suspect that Holstein, Denmark, and Scania, were likewise under water. To what extent the re-elevation of the British area was continued we shall most probably never be able to ascertain. All we know is that before it had attained even to its present level, snow-fields and glaciers had already made their appearance, and an arctic fauna lived round the shores of Scotland. Steadily encroaching upon the low grounds, those glaciers at last coalesced, while *nappes* of snow gathering upon all the hills of lesser elevation gave rise to little ice-caps, which, flowing down the slopes, gradually dilated upon the lowlands. Thus in time all Scotland became enveloped in ice that flowed west to break off in deep water beyond the Hebrides, and east to meet the Scandinavian *mer de glace* which had all the while been creeping outwards into the basin of the North Sea. The north of England was likewise shrouded in ice—part of its sheet coalescing with the Scottish *mer de glace* in the basin of the Irish Sea, and part with the united Scottish and Scandinavian ice-sheet that filled up the German Ocean. How far south in England that ice-sheet flowed still remains to be more rigorously determined. A broad belt of ice overflowed from the basin of the Irish Sea, and, uniting with the glaciers that descended from Wales, spread in the direction of the Severn Valley. In like manner the ice that flowed eastward from the Pennine Chain, to coalesce with the *mer de glace* of the North Sea, appears to have advanced into Lincolnshire. But in the high grounds of Derby the ice-flow may have been more or less independent, as it appears also to have been in Charnwood Forest. Ireland, with its lofty hills and humid climate, was, like Scotland and Wales, more or less buried in snow and ice, and its immense glaciers, uniting with those of Scotland and England, must have filled up the Irish Sea. The Channel-area, which had shared in the movement of elevation that succeeded the previous submergence, now also experienced a severe climate. Hard frosts split and ruptured the rocks; and *névé*, snow, and drenching rains spread the riven *débris* over the low grounds.

The southern limits reached by the last great ice-sheet in North Germany and Russia have yet to be defined. It overflowed, as we know, all the low grounds bordering on the Baltic, and advanced as far south at least as the 52d or 53d parallel of latitude in Germany, after which its terminal front probably turned away towards the north-east, just as that of the greatest *mer de glace* of a former glacial epoch had done.

Meanwhile, in all the mountain-regions of Central Europe large glaciers had reappeared, but they did not attain so great a development as those of earlier glacial epochs. The Carpathians, the Black Forest, the Vosges, the mountains of Central France, and the Pyrenees, each and all had their *nappes* of snow and glaciers; while the severity of the climate is shown by the quantities of angular frost-shattered *debris* which are widely spread over areas where no such detritus now accumulates. Even so far south as Gibraltar we have evidence of hard frosts and heavy snows, and probably in Malta a similarly extreme winter was experienced.

The rivers descending from all the glaciated regions poured vast bodies of muddy water down their valleys, and in summer when they rose in flood produced inundations on a scale far surpassing any *débâcle* that can now be witnessed in similar or more northern latitudes. Such, in a few words, were the climatic and physical conditions that supervened at the climax of the last glacial epoch. How were flora and fauna affected? Long before the winters of Northern France had become even so cold as they are at present, the southern forms must have vanished from that region, and as the cold increased the less hardy of the temperate forms would follow. The alpine plants, at the same time, would advance from the north and descend from the mountains, whither they had retired during the preceding interglacial epoch. Thus, by and by, a flora of polar willows, dwarf birches, and arctic and alpine mosses, saxifrages, and lichens would occupy the low grounds of Central Europe, while pines and firs would spread over Northern and Central France. We know that the arctic flora pushed its way south into Spain, Italy, and Austria, for a number of characteristic species are now living in the mountain-regions of those countries, whither they retreated upon the subsequent disappearance of cold climatic conditions in the low grounds. Among these are *Mulgedium alpinum*, Less., *Gnaphalium norvegicum*, Gunn., *Azalea procumbens*, L., *Arctostaphylos alpinus*, L., *Veronica alpina*, L., *V. saxatilis*, L., *Salix reticulata*, L., *S. herbacea*, L., *Juncus triglumis* L., *Woodsia hyperborea*, Br. Few of the arctic-alpine plants, however, seem to have crossed into Africa ; at all events they have not been recorded as occurring south of the Mediterranean, although many northern species are common to the flora of Europe and North Africa. According to Hooker and Ball, the most remarkable feature of the higher region of the Atlas is the very large proportion of common plants of the colder temperate regions of Central and North-western Europe, which are there found associated with species of very different types. With the doubtful exception of *Sagina Linnæi*, not one of the plants is characteristically alpine, or typical of the arctic or glacial flora.[1] During the southward advance of the temperate forms we can readily imagine what changes would take place in the interglacial flora of Southern Europe. The fig-tree, the Canary laurel, the vine, the judas-tree, and probably many others, became extinct in Southern France, some of them—for example, the fig-tree—dying out in Europe altogether. A similar fate befell the fauna—the great pachyderms of southern habitats vanished from our continent, and the temperate forms eventually took complete possession of the Mediterranean region. All these changes came about in a gradual manner, and hence each zone of latitude became in succession the head-quarters of the arctic and northern fauna and flora in their advance towards the south. Thus Palæolithic man must have hunted the reindeer in Southern England, Belgium, and Northern France, for many generations before the increasing severity of the climate compelled both to retreat. Step by step, however, man was driven south ; England and Belgium were deserted—perhaps even Germany, down to the foot of the Alps, was left unoccupied—until at last the Palæolithic race or races reached the south of France. It was at this stage that the mammoth entered Spain and Italy, the glutton lived on the shores of the Mediterranean, marmots frequented the low grounds at the base of the Northern Apennines, and pikas ranged the coast-lands of Corsica and Sardinia. In the low grounds of Aquitaine the reindeer roamed in great herds, and the musk-sheep, the glutton, the marmot, and other animals of northern or alpine habitats, were its congeners there. How far north the arctic fauna ranged during the climax of the last glacial epoch can only be conjectured. The reindeer were probably at that time summer visitors only in Northern France. England, covered for the most part with ice and snow, and washed upon its southern shores by the sea, was probably never reached by them. The Palæolithic population of Europe would be confined to the more southern parts of the Continent; but the hunters of Aquitaine may have followed the reindeer in their summer migrations to the north.

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[1] *Journal of a Tour in Marocco and the Great Atlas*, p. 231.

At last the glacial epoch reached its meridian, and the severity of the winters began to abate. Gradually the vast ice-fields of the north melted away, and the glaciers of the Pyrenees, the Alps, and other mountain-ranges, slowly shrank up their valleys. At or about this time, or it may have been somewhat earlier, the land-connections between Europe and Africa disappeared, and the Mediterranean, in some places at least, advanced upon what is now land. Traces of submergence, some of which are probably referable to this date, have been detected at various places on the Mediterranean seaboard.[1] The arctic fauna and flora, followed closely by the temperate species, now crept slowly north again. The reindeer, the musk-sheep, and their congeners, forsook the south of France—although it is not improbable that some of these may also have continued to linger on in the upper valleys of the Pyrenees and the Alps, long after the main body had vacated Central Europe.

In Scotland and Scandinavia the dissolution of the ice-sheet was accompanied by a submergence which in the former country was inconsiderable, hardly exceeding in the east and west of the central district 100 feet under the present sea-level, but increasing to 200 feet in the neighbourhood of the Moray Firth. Southern Scandinavia, however, sank to a depth of not less than 600 feet below the same datum-line. The seas were still cold, a highly arctic fauna living in the Scottish waters. In the east of England there are traces of a slight submergence, probably referable to this period, but so far as is known the subsidence was confined chiefly to Scotland and the southern region of Sweden and Norway, where it appears to have reached its maximum. The Baltic at this time, as some believe, communicated with the Arctic Ocean, and the climate of all Northern

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[1] As, for example, at Malaga (Ansted: *Quart. Journ. Geol. Soc.*, vol. xv. p. 599; in Corsica (Hollande: *Bull. Soc. Géol. France*, 3e Sér. t. iv. p. 186); in Sicily (Gemmellaro: *Atti della Accademia Gioenia*, 1859, t. xiv. p. 187); in Central and Southern Italy, where, according to Stefani, certain strata which hitherto have always been classed as younger Pliocene, such as those of Ficarazzi, Monte Mario, Vallebiaia, etc., ought more properly to be ranged with deposits of the Glacial Period. In these beds, he says, extinct species are extremely rare, while northern forms, such as *Cyprina islandica*, occur, which are wanting in the lower strata or true Pliocene. It is probable that the beds referred to are the relics of some earlier stage of the Glacial Period (see *ante*, p. 334) than that of which I speak above; (see *Boll. Com. Geol. Italia*, 1876, p. 209). Dr. Hoernes mentions the occurrence of raised shell-beds on the route between Kalamaki and Lumaki (Isthmus of Corinth) at nine to eleven mètres above the sea, and states that similar deposits are met with at many other places on the Mediterranean seaboard, such as the Morea, Rhodes, Cyprus, Pozzuoli, Algeria, etc.; (see *Bull. Soc. Géol. France*, 2e Sér. t. xiii. p. 571. They occur on the east coast of Tunis (Pomel: *Bull. Soc. Géol. France*, 3e Sér. t. vi. p. 217), and on the Barbary Coast (Ramsay and J. Geikie: *Quart. Journ Geol. Soc.*, 1878, p. 514).

Europe, notwithstanding the disappearance of the *mer de glace* from the low grounds, must have been still very ungenial.

We have now arrived at the closing scenes of the Glacial Period. Scandinavia and Scotland were re-elevated—the climate gradually moderated over all Europe—and the first chapter of Postglacial history began. The tracing-out of this history must be my task in the pages that follow, but I shall here anticipate certain conclusions, the reasonableness of which I hope to demonstrate in the sequel.

River- and lake-deposits, peat-mosses, and, in short, terrestrial accumulations of every kind pertaining to the last interglacial epoch, must have been greatly denuded during that succeeding and final Ice Age. We may readily understand how underneath the *mer de glace* that covered so wide a region in Europe all the more or less loose beds of clay, sand, gravel, turf, etc., would tend to be rudely pushed forward and ground up with the bottom-moraine of the ice. Here and there, perhaps, a patch of some river- or lake-deposit might be preserved—but this would be exceptional—at least in mountainous countries like Norway, Scotland, and the hilly parts of England and Ireland. But in lower-lying areas where the ice-flow met with no obstruction there would be less erosive action exerted, and we might therefore expect to find in such districts somewhat more plentiful relics of the last interglacial epoch, buried and preserved under boulder-clay. Again, those regions that lay beyond the reach of the *mer de glace* should exhibit their ancient lacustrine and fluviatile deposits in a comparatively intact condition ; unless, indeed, where these have been subjected to the action of the desolating floods and torrents that escaped from the melting ice-sheet. In cases where such a fate has overtaken them, we should expect to find the interglacial beds in great part rearranged, and often confusedly commingled with the shingle and detritus swept forward by the torrents. In other places, again, where they had been quietly overwhelmed by inundation-water, they might exhibit no confusion, but appear perfectly undisturbed below a less or greater thickness of loam, löss, or brick-clay. Such we might suppose would be the kind of treatment to which interglacial deposits in Northern and Northwestern Europe would be subjected during the closing glacial epoch. And the conditions would be very much the same in those portions of Central and Southern Europe which were exposed to the intensity of glacial and fluvio-glacial action. Even in regions that were neither glaciated nor swept by torrents and floods, we might yet reasonably expect to find the interglacial deposits frequently overlaid and obscured by superficial accumulations, formed at a time when the cold of winter was severer than at present. Now the mode of occurrence, the state of preservation, and the present distribution of the interglacial deposits, are precisely such as from the foregoing considerations we might have anticipated. Recalling certain evidence brought forward in preceding chapters, we may observe that in every instance in which relics and remains of the more characteristic Pleistocene mammalia and of Palæolithic man have been detected in countries where the glacial and fluvio-glacial accumulations of the last glacial epoch are strongly developed, they invariably occur either in or underneath the latter. In the more highly-glaciated regions, such as Scotland and Scandinavia, the interglacial beds appear as mere patches, more or less crumpled, confused, and abruptly truncated by the till that overlies them. Farther south, in the lower-lying regions of England and Northern Germany, where the ice flowed with an equable motion, the beds occur in a less patchy form under the boulder-clay, but they continue to give evidence of the enormous crushing weight to which they have been subjected.

It may be remembered that, during the latter part of the latest interglacial epoch, Wales and Ireland were submerged to a depth of at least 1200 feet, and that Scotland likewise was covered by a sea which overflowed the land up to 500 feet or thereabout above the present tide-mark. We know that this period of submergence must have endured for a long time, from the fact that the beds of sand which were then accumulated attain a thickness in England of several hundred feet. In Scotland the accumulation must also have been considerable, but during the succeeding glacial epoch all the Scottish deposits were scoured out by the ice, only a few patches being left here and there in the inland districts, while in the low-lying maritime regions, where, for reasons already given, the grind of the ice was less intense, the marine beds occur in better preservation, while the till that overlies them is often charged with shells belonging to different zones, which are rolled, crushed, broken, and scratched, just like the glaciated stones with which they are commingled. Here and there, too, we come upon horizontal rock-ledges cut in the face of hill-slopes that look out upon the sea—platforms and terraces which are evidently the work of the waves. But the interglacial age of these is shown by the fact that they are glaciated and coated here and there with boulder-clay. In Norway so intense was the glacial erosion that not a scrap of any marine deposit pertaining to the last interglacial epoch has been preserved, but it is possible, as I have suggested, that many of the ancient strand-lines (which are often smoothed-off and faintly-marked, while at least one of them shows glacial striæ) may have been formed contemporaneously with the similar rock-terraces in Scotland and the "middle sands and gravels" of Lancashire and Cheshire. In Wales the interglacial beds have been ploughed out by the glaciers, as Ramsay long ago showed, and in the more elevated parts of Northern England they have likewise been demolished. The same, too, is the case in Ireland. But in the lower-lying districts they appear often in more or less continuous sheets underneath the upper boulder-clay, which, like that of Caithness and the north of Lewis in Scotland, is often charged with marine exuviæ. It is needless to say that relics of ancient interglacial land-surfaces have been even less well preserved. Yet both in Scotland and England we come upon patches of terrestrial accumulations containing mammalian, molluscan, and vegetable remains, while in the till itself bones, tusks, and horns, and fragments of wood have been detected, which must have been rolled forward under the ice along with the general wreckage of the land. Precisely similar facts confront us in North Germany, where underneath the youngest till we encounter in some places clays with sea-shells, and in others beds of sand and clay with land- and freshwater-shells and bones of the Pleistocene mammals.

When we get beyond the southern limits reached by the upper boulder-clay, we enter a region which was swept by the floods and torrents coming from the *mer de glace*—the turbulent waters sometimes keeping to the valleys, at other times, when these were choked with frozen snow, overflowing upon the intervening plateaux. In this region, therefore, we often encounter wide-spread sheets of torrential gravels and sand in which may occur bones of the Pleistocene mammals and flint implements of Palæolithic workmanship—the relics of the last interglacial epoch. Occasionally the whole thickness of the superficial covering in these districts is composed entirely of such deposits, but now and again we find them overlying river accumulations of a more orderly nature, in which both Palæolithic relics and mammalian remains may occur in abundance.

In the great river-valleys of France the Palæolithic and ossiferous deposits are covered for the most part with that cloak of flood-loam or löss which marks the limits reached by the desolating inundations of the last glacial epoch. So likewise in the Rhine, the Danube, and other river-valleys of Germany, the ancient ossiferous gravels and lignites are buried under thick accumulations of the same loamy deposit. Entering the alpine lands of Central Europe, we see how the ice of the last glacial epoch has for the most part cleared out all interglacial accumulations, only a few inconsiderable portions having been preserved from the ravages of the ice-plough; and it is precisely the same in the hills of Central France and the Pyrenees. Even in regions which were neither glaciated nor subjected to fluvio-glacial action the ossiferous and Palæolithic deposits are yet frequently overlaid with massive accumulations of angular *débris*, which must have been formed under considerably colder conditions of climate than now obtain.

Are these facts, thus briefly recapitulated, sufficient to prove that Palæolithic man did not survive the last glacial epoch? Well, they go a long way to do so, and when their evidence is taken in connection with that furnished by the postglacial deposits, the result appears to me to amount to a demonstration that the manufacture and use of Palæolithic implements came to an end in our continent during the last glacial epoch. This I shall endeavour to make clear in the sequel, meanwhile I may take note of one objection to this view which has been urged by some English geologists. They tell us that Palæolithic implements occur in certain deposits that overlie the great chalky boulder-clay in Norfolk and other places, and these deposits are recognised by them as of postglacial age, simply from the fact that they rest upon boulder-clay. Now this conclusion would be inevitable if it were true that the great chalky boulder-clay had been laid down during the last glacial epoch. If that were the case no one could dispute their contention that Palæolithic man lived in England in postglacial times. And so long as geologists believed that the Glacial Period had been only one long uninterrupted period of cold conditions which came on gradually, reached a climax, and then gradually passed away, the conclusion I refer to was not only natural but one from which there was no possibility of escaping. We know now, however, that during the Glacial Period arctic and genial climates alternated, and that the great chalky boulder-clay is not the *moraine profonde* of the last glacial epoch, but belongs to a much earlier stage in the series. The occurrence of Palæolithic deposits overlying that boulder-clay is therefore no proof whatever that Palæolithic man lived in England in postglacial times. In like manner Palæolithic relics occur at Schüssenried in Würtemberg in a deposit that clearly overlies glacial detritus. But that morainic material is the product of what the Swiss call their first and greatest glacial epoch—the glaciers of the last cold epoch never flowed so far out upon the low grounds. Thus the superposition of the Schüssenried peat and tufa upon morainic material no more proves the postglacial age of these deposits, than the occurrence of beds of shale and sandstone upon the top of Mountain-limestone proves those to be Post-Carboniferous. To demonstrate the postglacial age of Palæolithic man, we must show that his relics and remains occur in true postglacial deposits—that is to say, in beds which have accumulated since the disappearance of the last great extension of glacier-ice in Europe. But, as I shall point out in subsequent chapters, there is no case on record of such an occurrence. Neither of Palæolithic man nor of the southern mammalia—the elephants, rhinoceroses, hippopotamuses, etc.—has a single trace been met with in any postglacial deposit. The most recent accumulations in which such traces appear are clearly of interglacial age. Thus in Scotland remains of the more characteristic Pleistocene mammals are met with underneath the upper or youngest boulder-clay, as at Crofthead, and the same is the case in England, as near Hull ; nowhere do they rest upon that boulder-clay or upon any of the marine clays with arctic shells of the Scottish maritime districts. In Central Europe, as at Tempelhof in Brandenburg and Utznach in Switzerland, they are in like manner covered by morainic materials. The same is the case in Italy, as at Leffe in the Val Gandino, and Pianico in the Val Borlezza. Then let us recall the fact that while the relics of Palæolithic man and the remains of his congeners are never found upon the surface of the younger or valley-löss, they yet frequently occur in and underneath that deposit ; while, in all the ancient river-drifts of Southern England and France, the evidence is no less clear that great and tumultuous floods occurred towards the close of the Palæolithic Period—the mud and loam from which invariably overlie the gravels containing Palæolithic relics. Again, this is in perfect harmony with the fact that in many caves, both in England and the Continent, the Palæolithic beds are covered with a more or less continuous and thick cake of stalagmite—which points to the lapse of a long period of time during which the caves remained unvisited either by man or beast. Take also in connection with this the frequent occurrence, upon the top of the upper stalagmitic pavements, of many large blocks detached from the rock above, or of tumultuous heaps of earth and angular *débris,* such as that accumulation of yellow clay with stones which forms so prominent a feature in the caves and rock-shelters of Belgium—separating the Palæolithic from the later Neolithic layers (a position which is also maintained by the löss in some of the same caves). Let us remember, likewise, how at Gibraltar and in Malta similar appearances present themselves, and the combined evidence becomes so overwhelming that we are driven to conclude that the Palæolithic Age came to a close with the last glacial epoch.

CHAPTER XV.

NEOLITHIC, BRONZE, AND IRON AGES.

Difficulty of ascertaining the relative antiquity of Neolithic relics—The Danish "kitchen-middens"—Views of Worsaae, Steenstrup, and Lubbock—Fauna of the "kitchen-middens"—Neolithic man—Conditions of life—Shell-mounds of Britain and France—Lake-dwellings of Switzerland—Dr. Keller on various forms of lake-dwellings—Human relics—Remains of plants and animals met with in ruins of lake-dwellings—Conditions of life—Passage from the Neolithic through the Bronze into the Iron Age—Relics of Neolithic and later archæological periods in other regions—"Long-heads" and "broad-heads" of British barrows—Celtæ, Belgæ, and Germani—Contrasts between Palæolithic and Neolithic Ages.

THE relics of Neolithic man have been met with in much greater abundance and over a vastly wider area in Europe than those of his Palæolithic predecessor. The latter are restricted to caves in various countries, and to certain alluvial deposits in France and the south of England, in which they occur more or less numerously, and to similar accumulations in Germany, Spain, Italy, and Greece, where, however, they have been less frequently encountered. But the weapons, implements, and ornaments of Neolithic times are strewn broad-cast over the Continent—from the shores of the Atlantic to the borders of Asia, and from Scandinavia and Russia to the Mediterranean. Our knowledge of the modes of life—the manners and customs—in a word, the state of civilisation of Neolithic man, is thus somewhat ample. We have still much to learn, however, and there is a great deal which will probably always remain obscure. It is not unlikely, also, that some of the views now more or less generally held with regard to the relative antiquity of various

Neolithic remains, may yet undergo considerable modification, or even be altogether abandoned. Archæologists have found much difficulty in determining the comparative antiquity of Neolithic implements by referring to the character of their workmanship. That the beautifully shaped and highly polished specimens of stone-work must be assigned to some advanced stage of the Neolithic epoch admits of little doubt, but then it is just as true that implements of a very rude character indeed have been found associated with these in such a manner as to lead to the conviction that both were used by one and the same people. Even in cases where all the implements in one particular "find," as in many "kitchen-middens," are rude and simple, it does not necessarily follow that they pertain to an early part of the Neolithic Age. So far as the evidence of the implements alone is concerned, they might belong to the very closing stage of Neolithic times. It is possible, in short, that they may be the relics of some poor or comparatively weak tribes who might have occupied Europe contemporaneously with stronger and more advanced races. Unfortunately the student of Neolithic archæology is in large measure deprived of the help which geology accords to the investigator who essays to interpret the records of Palæolithic times. It is only in rare cases that we find any superposition of later Neolithic upon earlier Neolithic accumulations. And even when such does occur it is often open to us to suggest that the difference between the implements of the two stages may not indicate the progress of any particular race, but rather point to the dispossession of one tribe by another. The succession of Palæolithic deposits testifies to the lapse of long ages, during the progress of which immense climatic and geographical changes took place, and we feel certain that the human implements obtained from the bottom layers are of much greater antiquity than those of the topmost beds. But it is seldom that the evidence of superposition in the case of Neolithic deposits is of such a decided character. For however protracted the Neolithic Age may have been, it was very inconsiderable indeed when contrasted with the prolonged duration of the preceding Palæolithic Period. Nay, the time which has elapsed from the close of the latter age even up to the present day cannot for a moment compare with the æons during which the men of the Old Stone Period occupied Europe. The deciphering of the relative antiquity of Neolithic remains is thus in large part the province of the archæologist and the anthropologist rather than the geologist. A close comparison of the human relics and remains has already cleared up much that was obscure, and we may hope that as time advances our knowledge of the different phases through which civilisation progressed during the New Stone Period will be considerably increased, and that we will yet learn much more of the various races which then occupied Europe contemporaneously or successively. For my present purpose, however, it will be sufficient to give a very brief account of some of the more interesting "finds" of Neolithic relics, with the view of showing the contrast that obtained between Neolithic and Palæolithic times.

Amongst the accumulations of Neolithic age which are thought by many archæologists to be oldest are the well-known "Kjökkenmödingr," or kitchen-middens of Denmark. These are heaps and mounds composed principally of shells of edible molluscs, of which the most abundant are oyster, cockle, mussel, and periwinkle. Commingled with the shells occur bones of mammals, birds, and fish in less or greater abundance, and likewise many implements of stone, bone, and horn, together with potsherds. The middens are met with generally near the coast, and principally on the shores of the Lymfjord and the Kattegat; they would appear, indeed, never to be found on the borders of the North Sea. They form mounds or banks that vary in height from three or five feet up to ten feet, with a width of 150 to 200 feet, and a length of sometimes nearly 350 yards. Where the shores are low and shelving, the mounds occur at only a few feet above high-tide mark, but they reach a somewhat higher level when the coast is more abrupt. They very often show hollows or depressions on the top, and such of them as have been excavated have disclosed layers of charcoal and small platforms of flat stones, which are evidently old hearths. The Danish savants (Forchhammer, Steenstrup, and Worsaae) who first examined these curious shell-mounds, came to the conclusion that they were the refuse-heaps which had accumulated round the dwellings of some ancient coast-tribe, and the depressions or hollows at the surface are supposed to indicate the position of the huts or tents, while the hearth-stones of course mark the sites of old fireplaces. Immense numbers of implements have been obtained from the middens, all, without exception, formed either of stone, horn, or bone; not a single trace of metal has yet turned up. The flint implements and weapons are very different in form from those fashioned by Palæolithic man, but they are nevertheless rudely finished, and seldom or never polished. Only a very few well-worked implements, most of them, too, broken or imperfect, have been met with, and this remarkable scarcity has given rise to some discussion, Professor Worsaae maintaining that the almost total absence of well-finished implements is good proof that the men of the Danish kitchen-middens lived in very early Neolithic times before great skill in the manufacture of stone implements had been acquired; while Professor Steenstrup, on the other hand, is of opinion that the rude denizens of the coast-lands were contemporaneous with other tribes occupying the inland districts who knew how to grind and polish their implements, and were in many respects farther advanced in civilisation. It is one of those nice cases in which Sir Roger De Coverly's decision—there is much to be said on both sides—must commend itself to the cautious archæologist. Sir John Lubbock remarks that he is unable altogether to agree with either, but he apparently leans to Professor Worsaae's view, for after an admirable summary of the evidence he concludes as follows:—"On the whole, the evidence appears to show that the Danish shell-mounds represent a definite period in the history of that country, and are probably referable to the early part of the Neolithic Age, when the art of polishing flint implements was known, but before it had reached its greatest development."[1] In a subsequent chapter I shall return to this question, when certain geological evidence will be adduced to show that the Danish kitchen-middens, although doubtless of great antiquity, most probably belong to a late Neolithic period; at all events that they can hardly be referred to the early age which Professor Worsaae claims for them.

It is worthy of note that the cockle, mussel, and periwinkle shells which compose so large a part of the kitchen-middens are larger than those of the same molluscs that now live upon the coast, while the oyster, formerly so abundant, has entirely disappeared—facts which point to the former salter condition of the Baltic Sea. It may have been, as Lyell has remarked, that "the ocean had freer access than now to the Baltic, communicating probably through the peninsula of Jutland, Jutland having been at no remote period an archipelago."[2] We must remember, however, that the position of the shell-mounds shows that the relative level of sea and land in that part of Denmark has remained apparently stable from the time of their formation to the present day. The total absence of shell-mounds along the west coast of Denmark is explained by the fact that the sea has made great encroachments there, and that any shell-mounds which may once have existed have probably been demolished along with the ground they rested upon.

The fish-remains found in the shell-mounds include those of herring, dorse, cod, flounder, and eel; and there are also bones of several birds. Of these last the most interesting are those of the capercailzie and the great auk (*Alca impennis*), a species which would appear to be now extinct. The mammalia are represented most abundantly by stag, roedeer, and wild-boar; but, besides these, were urus, dog, fox, wolf, marten, otter, porpoise, seal, water-rat, beaver, lynx, wild-cat, hedgehog, bear (*Ursus arctos*), mouse, and a small ox. The dog was domesticated, as was shown by the curious fact that those bones or parts of bones which a dog will devour are almost invariably wanting in the shell-mounds. No trace of any other domestic animal, such as ox (*Bos taurus*), sheep, goat, or hog, occurs, and the northern mammals of the so-called Reindeer period are likewise wanting.

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[1] *Prehistoric Times*, 4th edit., p. 253.

[2] *Antiquity of Man*, 4th edit., p. 14.

No human skulls have been obtained from any of the mounds, but those which are met with in certain tumuli, and here and there in the peat of Denmark, are believed to belong to the same date. They are small and round with prominent ridges over the eyes, and the facial angle is well developed. The type, in short, presents characters more or less analogous to that of the Lapps. The character of the relics and *débris* of the shell-mounds gives us a pretty good notion of the kind of life led by the old coast-tribes of Denmark. Ignorant, apparently, of agriculture, or of the use of textile plants, their highest art showed itself in the production of coarse hand-made pottery and chipped flints, for it is doubtful whether the very few polished stone implements that have been detected amongst the others were really fashioned by the shell-mound builders, or "conveyed" by them from some neighbouring people. Their only garments consisted probably of the skins of animals snared or killed in the chase. As to their food, oysters, cockles, and mussels doubtless formed a part, but it is not unlikely that these and other molluscs were also largely used for bait—the quantities of bones of herring, cod, and other deep-sea fish, showing that the fishermen were not afraid to trust themselves in their canoes for some distance from the shore. At other times they hunted, and the catalogue of birds and beasts secured by them evinces both skill and courage, and probably no small degree of cunning. Perhaps it was only when trapping, hunting, and fishing did not prove successful that they had resource to a molluscous diet. That they were sometimes, at all events, put to straits seems to be shown by the fact that they occasionally ate their dogs, the bones of which have been found split, for the sake of the marrow, in the same manner as those of other animals. We can picture to ourselves the little round-headed people coiled up under their skin-tents, or squatting round their fires, toasting fishes and roasting bones, very much as certain coast-tribes do at the present day. And perhaps Heine's graphic, if not very complimentary, description of the modern Laplanders gives us a faithful enough portraiture of the ancient fishermen of Denmark—

> "In Lappland sind schmutzige Leute,
> Plattköpfig, breitmäulig, und klein;
> Sie kauern ums Feuer, und backen
> Sich Fische, und quäken und schrein."[1]

Shell-mounds of similar character occur in other countries, as upon the opposite coasts of the Kattegat in Scania. In Scotland they are not uncommon, but are certainly of very various ages, some being as old at least as those of Denmark, while others belong to very recent times. They occur from levels of 2 or 3 feet up to 50 feet or so above the sea-level, and are met with on the shores of the Firth of Forth, of St. Andrews Bay, of Forfarshire, of the Moray Firth, in the Outer Hebrides, etc. Many of these are interesting from a geological point of view, and some reference to them will be found in a later chapter. No shell-mounds have been observed on the east coast of England, probably for the same reason that they are wanting on the west coast of Denmark. They occur, however, upon the west coast, and they are also met with in Ireland. Again, Delesse mentions the occurrence at Saint-Michel-en-Lherm (on the coast of Poitou north of La Rochelle) of mounds or heaps of oysters and other shells at 10 mètres above the sea, and 6 kilomètres from the shore, which are probably of the nature of kitchen-middens.[2]

Among the most interesting relics of antiquity which have yet been discovered are the famous lake-dwellings of Switzerland, described by Dr. Keller and others. They evince a considerably more advanced phase of civilisation than the kitchen-middens, and are further important from the fact that they reveal the successive stages through which the primitive inhabitants of Switzerland passed from the Neolithic through the Bronze into the Iron Age. Dr. Keller has given us an elaborate and detailed account of these remarkable dwellings,[1] and has arranged them in three groups according to the character of their substructure. Those of the first group, the *Pile Dwellings*, are, he tells us, by far the most numerous in the lakes of Switzerland and Upper Italy. In these the substructure consists of piles of various kinds of wood, sharpened sometimes by fire, sometimes by stone hatchets or celts, and in later times by tools of bronze, and probably of iron, the piles being driven into the bottom of the lake at various distances from the shore. Upon the heads of the piles platform-beams were laid and fastened by means of wooden pins ; in other cases, however, the cross-beams were fitted into mortises cut in the heads of the vertical piles. Occasionally cross-timbers united the piles below the platform, to steady and strengthen the structure. The platform consisted generally of one or two layers of unbarked stems laid parallel one to another, but in a few cases it was composed of boards split out of the trunks of trees. Frequently the outer row of piles appears to have been protected by a kind of hurdle-work of small twigs or branches. The dwellings were probably connected with the shore by means of a narrow platform also laid on piles, the remains of which have in some cases been detected. Dr. Keller remarks that, so far as can be ascertained, the same mode of construction characterised the pile-buildings of each of the three Ages of Stone, Bronze, and Iron, the only difference being that those which were occupied during the Bronze Age appear frequently to have been farther from the shore and deeper in the lakes than those which belong to the Age of Stone. Occasionally large numbers of stones were employed in strengthening the foundations of the dwellings. These are believed by Keller to have been brought in boats and thrown down between and around the piles, and he mentions that at Peter's Island in the Lake of Bienne a boat filled with stones is to be seen in the spot where it had sunk with its too heavy freight. The *Frame Pile-Dwellings* are very rare. "The distinction between this form and the regular pile-settlement consists in the fact that the piles, instead of having been driven into the mud of the lake, had been fixed by a mortise-and-tenon arrangement into split trunks, lying horizontally on the bed of the lake. This plan was chiefly followed where the bottom of the lake consisted of very soft mud, such as would hardly allow of a hold for the piles." In the *Fascine Dwellings*, as Dr. Keller terms his third group of lake-habitations, the substructure consisted of successive layers of sticks or small stems of trees built up from the bottom of the lake till they reached above the lake-level. Upright piles occur commonly in this curious foundation; they did not, however, support the platform, but appear to have been used simply as stays or guides for the great mass of sticks, which were built up between and around them. The foundations of the lake-dwellings are, as might be supposed, better known than the superstructures, of which, however, enough has been ascertained to give us a more or less definite idea of their character. The platform upon which they stood was covered over with clay, probably tramped or beaten down upon the rough surface of wood, and sometimes the clay enclosed a layer of pebbles. The walls or sides of the huts were formed of a wattle- or hurdle-work of small branches woven in between upright piles or stakes, and covered with a thick coating of clay. According to Keller, all the evidence hitherto obtained proves that the huts were rectangular, although some may possibly have been round. It is not known, he says, whether they were divided into several rooms or not. They would appear to have been thatched with reeds and straw, the remains of which are abundantly met with in every lake-dwelling. "Every hut had its hearth, consisting of three or four large slabs of stone; and it is probable, from the almost universal prevalence of clay-weights for weaving, that most, if not all, of them were furnished with a loom."

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[1] In Lapland are dirty people,
Flat-pated, broad-mouthed, and small;
They cower round the fire, toasting fishes,
And chatter, and screech, and squall.

[2] *Lithologie des Mers de France*, etc., p. 436.

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[1] *The Lake Dwellings of Switzerland and other parts of Europe*, by Dr. Ferdinand Keller (translated and arranged by John Edward Lee). 2d edition. 1878.

Lake-dwellings have been met with in many other regions of Europe besides Switzerland and Italy, as in Bavaria, Austria, Hungary, Mecklenburg, Pomerania, France, Wales, Ireland, and Scotland. The "Crannoges" of Ireland and Scotland were rather artificial islands than dwellings like those described above. They come nearest in character to the Fascine Dwellings, some of them being built up in the same manner with layers of sticks strengthened and surrounded by vertical piles, while others were composed of earth and stones, or of a mixture of these with branches and stems of trees. Mention may be made also of the traces of log-houses which have been found in certain peat-bogs in Ireland, and of the curious pit-like dwellings or "hut circles" which have been met with in various places in England. Some of these no doubt go back to Neolithic times, but many were in use down to a much more recent period.

Immense numbers of implements (see Plate C),[1] weapons, fragments of pottery, and bones of various animals, have been discovered in the *débris* of the old lake-dwellings, the character of which gives us some notion of the kind of life led by the ancient Lakemen. During the Neolithic Age they were so far advanced that they knew how to till the ground and to cultivate wheat and barley, which seem to have formed a principal article of food. Flax also was grown by them, and largely employed in the manufacture of cord, netting, ropes, and of mats, coverings, and cloth, many pieces of which have been preserved to testify to their skill as weavers. Quantities of potsherds are found on the sites of the old dwellings, some portions showing patterns and ornamentation, and the designs of the various cups and vessels which have been discovered prove that, although igno-

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[1] The illustrations in Plate C are from Dr. Evans's *Ancient Stone Implements, Weapons, and Ornaments of Great Britain.* Fig. 1 represents the face (*a*) and side (*b*) of a flint celt, which is ground at the edge only. Fig. 2 (*a* and *b*) is a polished celt of a tough jade-like stone. Fig. 3 is an axe-head of felstone. Fig. 4 is a flint arrow-head. All the implements are British, and characteristically Neolithic.

PLATE C.
To face page 372

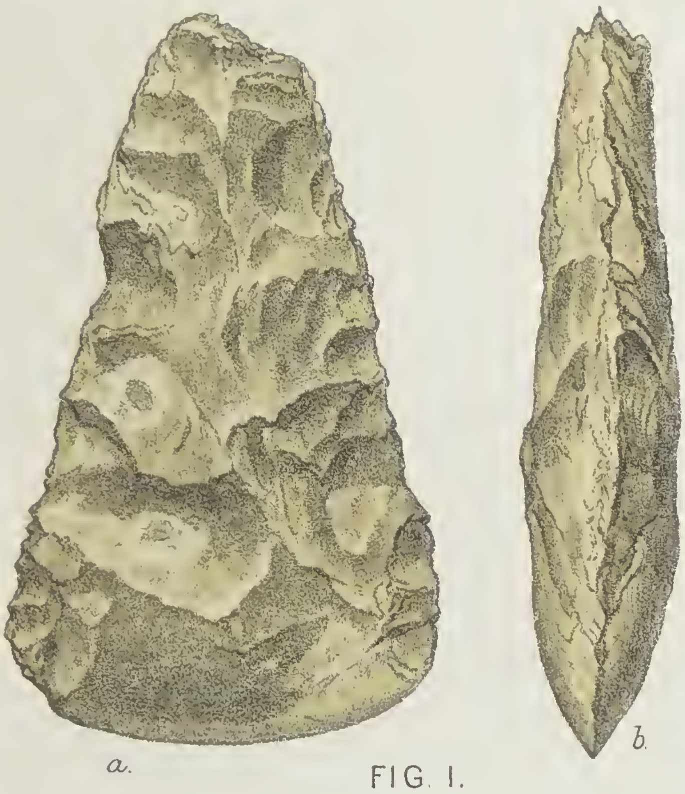

FIG. 1.

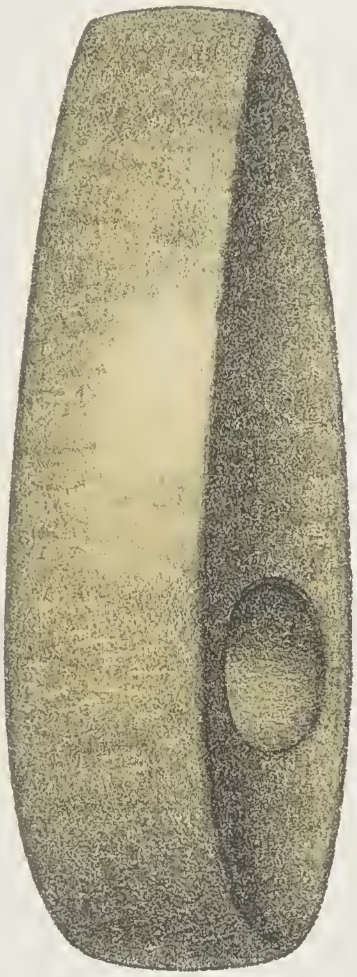

FIG. 3.

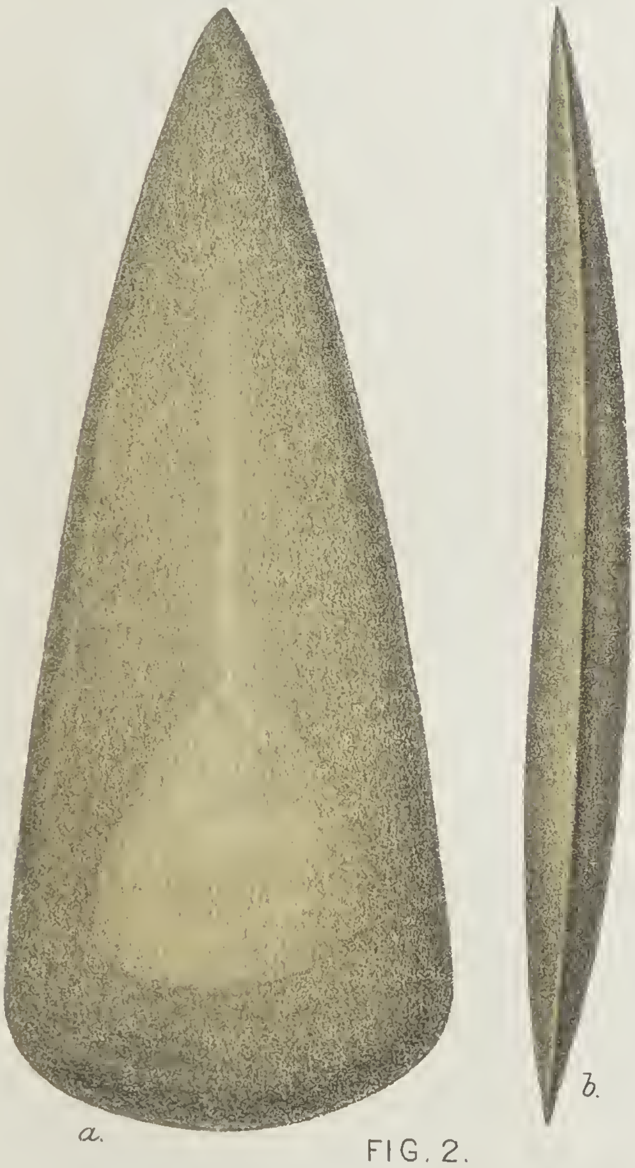

FIG. 2.

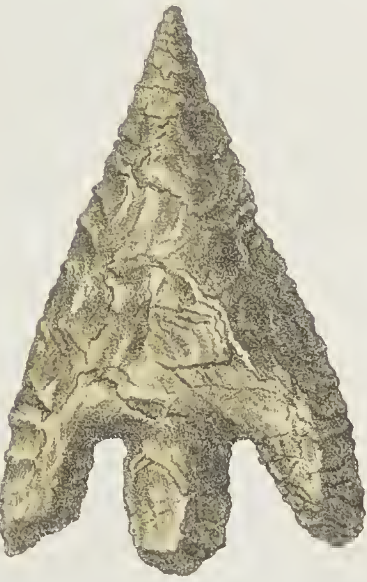

FIG. 4.

NEOLITHIC IMPLEMENTS

rant of the potter's wheel, the lake-dwellers were yet not unskilled in the manipulation of clay. Of stone implements there is likewise a great abundance, but flints are not nearly so numerous as in the Neolithic "finds" of Western Europe. For their celts and chisels they selected many different kinds of stone, a preference being of course given to those which combined toughness with hardness. That they did not employ flint more commonly is explained by the circumstance that this variety of stone is met with only very sparingly in Switzerland. Implements of horn, bone, and wood, were also in common use. But the contrast between Neolithic and Palæolithic times is still further emphasised by the fact that the lake-dwellers were accompanied by domesticated animals—by sheep, goat, ox, horse, pig, and dog, and some of these were accommodated in stalls adjoining the huts occupied by their owners. In the heaps of refuse which accumulated on the bottom of the lakes underneath and in the immediate neighbourhood of the platforms, are found many remains of wild mammals, birds, fishes, and reptiles, from which we learn that the lake-dwellers snared and hunted such animals as fox, marten, polecat, wolf, wild-cat, beaver, elk, urus, bison, stag, roedeer, and boar. Amongst the birds are the golden eagle, falcons, owls, starling, crows, pigeon, grouse, stork, heron, crane, coot, gulls, swan, goose, ducks, etc., the water-birds, as might have been expected, predominating. The amphibians and fish were all of common indigenous species, such as frogs, perch, bleak, pike, etc. Not a trace of any of the characteristic Pleistocene mammalia appears, even the reindeer seems to have been unknown, although it occurs in postglacial and Neolithic accumulations in Britain.

Professor Heer has shown that some of the plants cultivated by the lake-dwellers are not indigenous, but must have been introduced. Such are the Egyptian wheat (*Triticum turgidum*) and the six-rowed barley (*Hordeum hexastichon*). Along with these there is found a South European weed (*Silenc cretica*), which was doubtless introduced accidentally at the same time. This, taken in connection with the fact that the swine, sheep, goat, and probably some of the oxen, are descended not from indigenous European but from Asiatic species, renders it in the highest degree probable that the Neolithic inhabitants of Switzerland came originally from the east, bringing with them their cereals and domestic animals.

According to Dr. Keller, the passage from Neolithic times to the Age of Bronze was effected peacefully and gradually. There is no evidence to show that a bronze-using people suddenly invaded Switzerland and overwhelmed their Neolithic predecessors. All the facts would seem to point to a gradual introduction of metal. At first, owing probably to its actual scarceness and the want of metallurgic knowledge on the part of the lake-dwellers, it was very little used. Perhaps the earliest implements of bronze were obtained by barter and imported. By and by, however, the ores themselves would be introduced, and the people would little by little acquire more dexterity in the manufacture of such implements and weapons as they were in need of. But stone certainly continued to be employed contemporaneously with bronze. The pottery of the Bronze Age shows some advance upon that of Neolithic times, but the potter's wheel had not yet apparently come into use. The remains of the domesticated animals occur more numerously in the settlements pertaining to the Bronze Age, from which it has been inferred that flocks and herds were more abundant then than in the preceding Age of Stone. The conditions of life, however, would appear not to have differed in any essential degree. The possession of metal implements would no doubt be of great service to the people, but they still continued to be a race of agriculturists, fishers, and hunters. Of the people themselves we know but little, human remains being very rarely met with in the lake-dwellings. It is most probable, however, that they were of the same types as those whose remains occur in the numerous tumuli or burial-mounds and cromlechs which are distributed over so wide an area in Europe. We are equally ignorant of their religion, and there is nothing to indicate what kind of government and social order they had. Amongst the relics pertaining to the Bronze Age are certain crescents of earthenware which are supposed by Dr. Keller to be sacred emblems of the moon, "by means of which, as with the branches of the mistletoe, they imagined they were able to avert and to cure diseases. This panaceum was probably erected in some open space, perhaps over the doors of the dwellings, so that the ornamented side was exposed to view." Sir John Lubbock, however, thinks it is more probable that they were pillows. "Though this," he says, "seems at first very unlikely, and they must, one would think, be very uncomfortable, still we know that several barbarous races at the present day use wooden pillows or neck-rests of the same kind, as, for instance, the Figians, who, having enormous heads of hair, sacrifice comfort to vanity, and use a mere wooden bar for a pillow. The very long bronze pins found with these 'crescents' indicate that during the Bronze Age the hair was worn very long, and was carefully arranged."

The lake-dwellings continued in use down to the Iron Age, and even to the times of the Romans, as we know from the fact that Roman implements have been found commingled with those of stone and bronze on not a few of the old sites.

Memorials of the Neolithic, Bronze, and Iron Ages are scattered plentifully over Europe. Amongst the most striking of these are the barrows, cromlechs, standing-stones, and other "rude stone monuments." An examination of the barrows has shown that these in the great majority of cases are sepulchral mounds, the contents of which have yielded to archæologists much interesting information as to the various people who have successively occupied the land. It has been shown that those ancient tumuli belong to very different ages, some of them dating back to Neolithic times, many pertaining to the Bronze Era, while not a few have been assigned to the Iron Age, and even to the post-Roman period. In Britain there are two kinds of tumuli, the long barrows and the round barrows, the former of which are of Neolithic Age, while the latter are referred partly to the Bronze Age and partly to more recent times. The people who constructed the long barrows were a *dolichocephalic* or "long-headed" race, while those by whom the round barrows were raised were *brachycephalic* or "broad-headed." The "long-heads" of Britain were unacquainted with the use of metal, which would appear to have been introduced by their "broad-headed" conquerors, who constructed the round barrows. In Switzerland, however, a knowledge of metals was apparently acquired in a peaceful way by tribes who had formerly used only stone, wood, and horn. Of the relics met with in the more ancient tumuli it is not necessary for me to speak further than simply to say that they are strongly marked off in character and appearance from the rude and simple relics of Palæolithic times. Remains of various domesticated animals are frequently encountered in Neolithic burial-places, and hand-made pottery is also occasionally met with.

It is believed by some that the "long-heads" are represented in Europe at the present day by the Basques of North-western Spain, the swarthy Frenchmen in Aquitaine, and the small dark Welshmen of Denbighshire, and the dark-haired people in the south-west of Ireland. If this be true, then we may believe that the "long-heads" were a short-statured folk, with dark hair and eyes, and a complexion to match. Whence they came can only be conjectured. Some say from Africa, but Professor Dawkins suggests, with what seems greater probability, that they entered Europe from the east, starting "from the central plateau of Asia, from which all the successive invaders of Europe have swarmed off." The "broad-heads," who pushed back and dispossessed the "long-heads," have been identified by Mr. Dawkins with the Celtæ, who would thus date back in Britain and France to the close of the Neolithic Age. They held their own in North-western Europe all through the Bronze Age down to the dawn of history, when, according to the same writer, they had to bide the shock of a new folk-wave, that of the Belgæ, just as the Belgæ in Cæsar's time were assailed by the Germani.[1]

Neolithic man was frequently a cave-dweller, his hearths and the *débris* of his feasts having been met with in many caves in England, Belgium, France, Spain, and other countries. In all these regions the animal remains with which the Neolithic relics are associated belong to species which are indigenous to the same districts in which the caves occur, or are known to have been living there in historical times. Thus in the caves of the Pyrenees in Ariége, explored by MM. Garrigou and Filhol, are found remains of oxen (*Bos primigenius, B. frontosus, B. brachyceros*), a sheep like that which is often met with in the peat-bogs, goat, stag, roe-buck, wild-boar (*Sus scrofa ferus* and *palustris*), brown bear, wolf, dog, fox, chamois, and many birds. The same authors mention a number of facts which lead them to suspect that cannibalism may have been a custom with the Neolithic cave-dwellers of Ariége.[1] In certain tumuli of our own country Dr. Thurnam thought there was evidence in the appearance presented by the burnt, broken, and scattered fragments of skulls and human bones of the same horrible custom having prevailed among the "long-heads" of Britain. But Mr. Greenwell, who was for some time impressed with the force of Dr. Thurnam's argument, now concludes from subsequent careful analyses of the evidence that this view cannot be maintained.[2] There can be no doubt, however, that the Neolithic peoples quarrelled, fought, and killed with as much readiness as the savage tribes of Africa do at the present day. Many of their implements can only have been intended for weapons of war, and their fortified dwelling-places and camps show that "the good old rule, the simple plan," was well understood and acted upon in Neolithic times. It may be inferred also that the people had a belief in a future state from their custom of burying weapons, implements, and ornaments in graves, and of placing a vessel supposed to have contained food beside the dead, customs which still prevail amongst many modern savage tribes. But with regard to their religious ideas we can only indulge in vague guess and conjecture.

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[1] For a clear and interesting account of these migrations see Boyd Dawkins's *Cave-hunting*, p. 220 *et seq.*; and *Early Man in Britain*, chaps. ix.-xii.

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[1] *Age de la Pierre Polie dans les Cavernes des Pyrenees Ariégeoises*, p. 61.

[2] *British Barrows*, p. 544.

It is of course quite impossible in very many cases to correlate the Neolithic, Bronze, and Iron Ages of one country with the similar stages in the history of other regions. We may say in a general way that the Neolithic cave-dwellers of Wales, Belgium, the Pyrenees, and other areas, and the constructers of the long barrows in Britain, were contemporaneous with the Neolithic lake-dwellers of Switzerland. But the subsequent Bronze Age would, no doubt, commence in some places earlier than in others. We cannot tell how or in what way a knowledge of metals was introduced. In Switzerland, as we have seen, it would appear to have been acquired in a peaceful way. But we can readily believe that before the universal diffusion of metallurgical knowledge, those tribes who had possessed themselves of bronze weapons might now and again invade and overcome people, who, owing to poverty, ignorance, or the inaccessibility of their country, had remained for a much longer time in the Neolithic phase of civilisation. We know, indeed, that this was actually the case, and that people in the north of Scotland were living very much after the same manner as the Danish shell-mound builders, destitute apparently of metallic implements, long after the Bronze Age had been succeeded by the Age of Iron.

This very short and imperfect outline of the later archæological periods will yet suffice to show how great the gap is that separates Palæolithic from Neolithic times. During the closing scenes of the Palæolithic Period Europe passed through its last excessive glacial epoch—man was then associated in the south of France with the arctic mammalia; but when we first meet with Neolithic man we find him surrounded by a group of animals that differs in no essential degree from the present fauna. Palæolithic man had no knowledge of agriculture; he was ignorant of weaving and the potter's art, nor does he appear to have had any domestic animals. Neolithic man on the other hand was deficient in none of these respects; he seems to have excelled his Palæolithic predecessor in everything save in art. There are no sculptures, no etchings or outline-drawings of animals, pertaining either to the Neolithic or the Bronze Age that can equal the marvellous work of the reindeer-hunters of Périgord and the Pyrenees. Even the drawings of the modern Eskimo are stiff and poor when placed in comparison with the more perfect etchings of the Reindeer period. Notwithstanding his wonderful artistic gift, however, Palæolithic man lived very much in the same state as the wild animals which he hunted. The accomplishments of Neolithic man, if less striking, were certainly more conducive to his comfort. It is a fine thing to be endowed with artistic capabilities; but after all, were we to be deprived of the good things which came in with our Neolithic progenitors—had we no looms, no earthenware dishes, no corn, no horses, dogs, cows, nor sheep—I fear we should hardly feel ourselves recompensed for the want of these by the possession of a notable artistic talent. Between Palæolithic and Neolithic man there is thus a wide gulf of separation. From a state of utter savagery we pass into one of comparative civilisation. Was the Neolithic phase of European archæological history merely developed out of that which characterised Palæolithic times? Was the European Neolithic man the lineal descendant of his Palæolithic predecessor? There is no proof either direct or indirect that this was the case. On the contrary, all the evidence points in quite an opposite direction. When Neolithic man entered Europe he came as an agriculturist and a herdsman, and his relics and remains occur again and again immediately above Pleistocene deposits in which we meet with no trace of any higher or better state of human existence than that which is represented by the savages who contended with the extinct mammalia.

I have already made some reference to the physical evidence of this break or hiatus, and I shall have something further to say about it in succeeding pages. Meanwhile, it is clear that even if that evidence were altogether ignored, we should yet be compelled to admit that a long interval was required for the great change that took place in the fauna and flora of Europe. Nearly all the more characteristic southern mammals which occupied Europe along with Palæolithic man during the last interglacial epoch, disappeared from our fauna before the close of the succeeding glacial era—some of them retiring to more southern climes, others dying out altogether. Even the arctic or northern group, which at the climax of glacial cold had sought refuge in the south, had slowly migrated north again with the return of more clement climatic conditions, so that when Neolithic man made his appearance the temperate fauna had once more come into possession of Central Europe. The last glimpse we obtain of Palæolithic man is in Southern France, where the reindeer and its alpine and northern congeners were his companions ; the first glimpse we get of his Neolithic successor is in Middle Europe, from which the northern fauna and flora had already taken their departure. "Speaking in general terms," says Professor Dawkins, "the wild fauna of Europe as we have it now dates from the beginning of the Prehistoric [Neolithic] Age, and consists merely of those animals which were able to survive the changes by which their Pleistocene congeners were banished or destroyed. The arrival of the domestic animals under the care of man in the Neolithic Age, and their extension over the whole of Europe in a wild or semi-wild state, coupled with the disappearance of the wild species [which were contemporaneous with Palæolithic man], constitute a change as important as any of those which define the Meiocene from the Pleiocene, or the Pleiocene from the Pleistocene Periods."

CHAPTER XVI.

POSTGLACIAL AND RECENT DEPOSITS OF THE BRITISH ISLANDS.

Physical conditions of late glacial times—Scottish Postglacial beds—Raised-beaches—Estuarine and river-deposits—Organic remains—Submarine forests and peat—Buried forest, etc., of Carse of Gowrie, etc.—Succession of deposits—Glacial and late glacial accumulations of 100-feet terrace—Postglacial river-detritus—Ancient land-surface and vegetable remains under Carse-clays—Origin of Carse-clays—Connection of these clays with torrential gravels—Postglacial deposits of the Forth valley—Vegetable remains—Kitchen-middens of 45–50-feet beach—Postglacial deposits of the Montrose Basin—Succession of changes—Date of last elevation of land.

We have now to inquire into the climatic and geographical conditions which obtained during Postglacial and more recent times. We have seen that the latest phase of the Ice Age was severely glacial, and that the youngest deposits of that period tell us of a time when the Scandinavian peninsula was submerged for some 600 feet or thereabout below its present level; while in like manner the sea overflowed considerable tracts in the low-lying maritime districts of our own islands. A cold ocean, stocked with arctic and boreal shells, washed the shores of Scotland, while large snow-fields covered the higher grounds, and glaciers of no mean size occupied the mountain-valleys, and even in some cases descended to the sea-level. Snow-fields and glaciers likewise existed in the hilly districts of England, Wales, and Ireland. In Norway, too, very large glaciers still filled certain of the fiords and calved their icebergs in the sea. Again, in the alpine regions of Middle Europe, great snow-fields also continued to feed extensive *mers de glace*, and the rivers of the Continent carried down in flood-time immense quantities of fine mud, with which they covered wide areas in the low grounds. Such, in a few words, were the physical conditions of "late glacial times."

For reasons which will become obvious as we advance in our inquiries, the passage from those times to the Postglacial Period cannot always be traced. There would often appear to be a gap or hiatus in the evidence, for frequently we pass at once from true glacial beds into overlying accumulations of postglacial age, which give proofs of very different climatic conditions. Sometimes, for example, we find that clays well charged with arctic shells are overlaid directly with peat containing abundant roots and trunks of large oaks and other trees. In this case it is clear that certain evidence is wanting. We may be sure that the climate could not have changed in the twinkling of an eye. The bed of an arctic sea has been converted into dry land, and the climate has become temperate, but the deposits in which the gradual amelioration of climate might have been traced are wanting. Numerous examples of this phenomenon occur in our maritime regions, as I shall point out presently. In the inland districts there is often a similar appearance of a want of continuity between late glacial and postglacial times. But the want of continuity is in such cases only apparent, as certain discoveries made in recent years have clearly demonstrated. This will come out clearly, I hope, in the sequel: meanwhile, we must take a glance at the evidence supplied by the postglacial deposits of our islands and the Continent before we attempt to grapple with the more general questions which such a review of the facts will suggest. Confining myself first to a mere description of details, I shall briefly indicate the conclusions to which these directly lead, and, thereafter, I shall sum up the general evidence and endeavour to discover what light it throws upon the succession of climatic and geographical changes which characterised Europe in postglacial times. It will be most convenient to begin with the evidence supplied by our own country, and as the succession of postglacial deposits and the relation of these to accumulations of glacial age are perhaps better displayed in

Scotland than in other parts of the British area, I shall commence with a short account of the Scottish series.

The Scottish beds consist of gravel, sand, clay, silt, and peat, or of marine, estuarine, freshwater, and terrestrial formations. The marine deposits are represented by benches and terraces of gravel and sand, which are more or less well charged with the relics of a fauna closely approximating in character to that still living round our shores. They are, in short, raised-beaches, marking former levels of the sea. Upon the exposed sea-coasts the postglacial raised-beaches do not attain a greater elevation than 45 or 50 feet. But when these are followed inland along the course of the larger estuaries they are found to rise to a somewhat greater height. Twenty-five feet or so lower down occurs the best marked of all the raised-beaches—that upon which most of the seaport towns and villages are built. Sometimes this beach is represented by a mere narrow rock-ledge, at other times it forms a broad plain rising inland with a gentle gradient until it terminates suddenly against what appears to have been the old coast-line. Along the margins of the large estuaries this beach also rises imperceptibly as we trace it inland until it merges with old alluvial flats of fluviatile origin, the surface of which may be as much as 45 or 55 feet above the mean level of the sea. Thus in the estuary of the Tay we have the wide plains known as the Carse of Gowrie, the similar "haugh-lands" of the Earn, an affluent of the Tay, and the broad flats or "Inches" at Perth. The average elevation of the Carse of Gowrie does not exceed 30 feet above the sea, but as we follow the flat land towards Perth we find that it gradually rises until it attains a height above the same datum-line of 38 or 40 feet. Proceeding still farther up the valley the same terrace gradually merges into river-alluvium and gravel at 50 feet or so above the sea. Similar more or less extensive plains occur along the borders and at the heads of most of the Scottish estuaries and firths, such as the Carse of Falkirk and Stirling in the Forth valley, the flats that margin Inverness Firth, Beauly Firth, Cromarty Firth, Dornoch Firth, Solway Firth, Wigton Bay, the Clyde, etc. Wherever, indeed, a considerable valley opens more or less directly upon the sea, we find the lower reaches of its river almost invariably flowing through tracts of flat country, the upper surface of which may reach from 5 or 10 to 20 or 30 feet above the level of the sea. These flats, however, when they are followed inland begin in a shorter or longer distance from the sea-coast to rise with a more or less gentle gradient, and so pass gradually into what we at once recognise as old terraces of fluviatile formation. Along the margins of the open sea the raised-beaches are generally narrow, and this is most markedly the case where the coast is more or less abrupt. Thus, in many places, the sea is bordered by a mere narrow strip of flat ground not exceeding a hundred yards in breadth, and abutting abruptly against rock-cliffs, the under portions of which often show old sea-worn caves and gullies. In other districts, again, where the land descends with a gentle gradient to the shore, the raised-beaches sometimes attain a width of one or two miles or even more.

The organic remains occurring in these beaches and estuarine flats consist of the common forms that are still indigenous to our coasts, such as cockle, mussel, oyster, periwinkle, *Scrobicularia piperata*, *Hydrobia ulvæ*, *Tellina balthica*, etc. The presence of the large Greenland whale, however, remains of which have been met with in the great estuarine flats of the Forth, is not without its significance, and may possibly point to a somewhat colder sea than the present. But on the other hand we find on the borders of the Firth of Clyde a postglacial accumulation of shells, some of which seem to bespeak milder conditions of climate than the present. Mr. Crosskey has drawn special attention to this deposit. "It contains such shells," he says, "as *Psammobia ferroënsis* and *Tellina incarnata* (*tenuis?*), of larger size and in greater numbers than they at present occur living in the neighbouring seas," a fact indicating, he thinks, conditions of climate possibly more genial than those which exist at the present day.

The postglacial deposits of Scotland frequently rest directly upon glacial accumulations, and between the two series there is unquestionably a "break." We find no "passage-beds" between the two sets of deposits; no appearance of a gradual change from arctic to boreal and temperate conditions. The beds which seem to afford some such evidence belong entirely to the postglacial series. I thought at one time that we had some trace of a passage from arctic to temperate conditions in the brick-clays and Carse-deposits of the Forth, but the Carse-clays have since been found in several places to rest unconformably upon the arctic shell-beds.

Dr. Gwyn Jeffreys has indeed described the occurrence at Fort-William of old beach-deposits in which occur a number of species of molluscs, such as *Lacuna divaricata, Pleurotoma turricula,* etc., that have a somewhat northern range, commingled with the common forms of our present coasts, and one species, *Pecten islandicus,* which is no longer a native of our seas, but is widely distributed in the Arctic Ocean. But there is reason to believe that there are really two deposits at Fort-William—the one being of late glacial, and the other of postglacial age. I am inclined, therefore, to believe that the unconformity between the glacial and postglacial deposits, upon which Messrs. Crosskey and Robertson have insisted,[1] will be found to hold true for Scotland generally.

Among the most interesting and important of the Scottish postglacial beds are the so-called "submarine forests and peat." These vegetable-layers have been observed at many different places at and below high-water mark. They vary in thickness from a few inches up to four or five feet, and are made up principally of the remains of trees and other land-plants. Sometimes they repose directly upon true glacial deposits, in other places they are underlaid by river-sand and gravel, and alluvial silt and clay. In the estuaries of the Forth and Tay they clearly belong to an older date than the raised-beaches and great Carse-lands, since they everywhere pass underneath the marine and estuarine postglacial beds. As there is no district perhaps where they can be studied to better advantage than in the lower reaches of the Tay and the Earn, a short description of that region will serve to show the general mode of their occurrence, and the nature of the deposits with which they are usually associated.

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[1] "Monograph of the Post-Tertiary Entomostraca."—*Palæontographical Society,* 1874.

The accompanying illustration brings into one view the more prominent features of the late glacial and postglacial accumulations as these are developed in the valleys of the Tay and the Earn. Resting upon the strata of Old Red Sandstone age comes first a mass of tough reddish boulder-clay (1), overlying which we find a considerable thickness of gravel, sand, and brick-clays (2). Next in ascending order are beds of gravel, sand, and silt (3), resting upon an eroded surface of the underlying deposits. Above these younger sand- and gravel-beds appears a stratum of peat (4), surmounted by a widespread accumulation of silt and clay (5). To a still later period belong the alluvial deposits (6). Let us now glance at the more salient characteristics of each of these divisions in succession, and see what they have to tell us of physical and climatic changes.

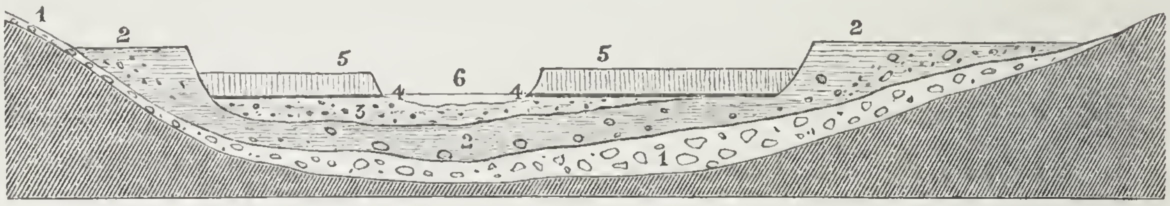

Fig. 11.—Diagrammatic section across Carse of Gowrie. 1, Till; 2, Late glacial clays, etc.; 3, River-shingle, gravel, etc.; 4, Peat and forest-bed; 5, Carse-clay; 6, Recent alluvia.

1. The *Till* or *Boulder-clay* need not detain us. It is a highly typical glacial accumulation, and represents the bottom-moraine of the last ice-sheet which overflowed all the low grounds of Scotland.

2. Resting upon the denuded surface of this boulder-clay comes a series of aqueous deposits, consisting in some places of shingle and boulders, or of gravel and sand, and in other places of fine brick-clays. The upper surface of these deposits is comparatively flat, and reaches 100 feet above the sea-level. They appear at one time to have filled up to that level the whole of the lower reaches of the valleys of the Tay and the Earn, and their denuded remains still form a more or less well-marked

terrace, which may be traced often for miles along the slopes of the valleys. They fringe most of the so-called Inches in the Carse of Gowrie, and spread out in broad sheets and plains in the Earn valley above Forgandenny, and in that of the Tay a little to the north of Old Scone. Their upper surface, as I have said, is just 100 feet above the sea-level, and they maintain the same level all the way from near Dundee to some miles above Dalreoch in the valley of the Earn, and to Luncarty above Perth in that of the Tay. But when we trace them farther inland, we find they gradually rise in elevation and pass into flats and terraces of river-gravel and sand. Judging, therefore, merely from the mode of their occurrence, we should say that the deposits of the 100-feet terrace were of estuarine formation. In the upper reaches of the valleys they consist principally of gravel, shingle, and sand, but in the wider and opener areas they are made up to a large extent of brick-clay, which is usually finely laminated, and often contains scattered stones and large erratics. Along the margin of the deposits such large erratics occur here and there in great abundance. Near Errol, in a brick-clay belonging to the series under review, marine shells have been obtained in considerable numbers. They belong to species which are now characteristic of high northern latitudes, and include such extremely arctic forms as *Pecten grœnlandicus, Leda arctica, Tellina myopsis,* etc.

From these facts we gather that after the disappearance of glacier-ice from the lower valleys of the Earn and the Tay, the sea encroached upon the land, and reached to a height of 100 feet or so above its present level. The climate was still very cold; glaciers probably continued to occupy the upper reaches of the valleys; and great bodies of muddy water derived from the melting snow and ice flooded the low grounds in summer, and swept down to the estuary heaps of shingle, gravel, and sand. Similar freshets descending from small lateral valleys in the Ochils formed great *cônes de déjection* of detritus, as they escaped from their gullies to mingle their waters with those of the estuary. Much river-ice, carrying gravel, stones, and occasional large erratics, floated out to sea, and now and again dropped their burdens on the way. No trace of land-plants or land-animals has yet been met with in these ancient estuary-deposits, as we may be sure they would have been had either abounded. The intensely arctic character of the marine fauna, the common occurrence of ice-floated stones and boulders, the tumultuous aspect of the flood-gravel and shingle of the swollen torrents which poured into the estuary on every side, all testify strongly to the severity of the climate. The upper reaches of the estuary must have been greatly freshened by the influx of ice-cold water, and that is perhaps the reason why no marine organic remains occur in the estuarine deposits above Errol. We must not forget, however, that over wide areas the deposits in question are concealed under newer accumulations, and were they better exposed to observation they might possibly be found to contain a more abundant fauna than they have yet yielded.

Such, then, appear to have been the conditions under which the late glacial deposits of the Tay and the Earn were accumulated. They are contemporaneous with the great kames and gravel-flats which cover extensive areas in the low grounds that sweep up to the base of the Grampians. A gradual passage can be traced from the true estuarine beds into flood-gravels of fluviatile and torrential origin, and these latter are closely associated with coarse shingle, and rounded boulders, and earthy *débris*, and angular erratics, which cumber the lower reaches of the mountain-valleys, where they assume the form of true moraines. The last continuous ice-sheet had melted away from the low grounds, and the glaciers which still occupied the mountain-valleys were gradually retreating under the growing influence of milder climatic conditions.

3. The beds which immediately overlie the late glacial deposits of the Tay and Earn carry us with a leap into a very different condition of things. They consist of river-gravel, sand, and silt, and rest upon a highly denuded surface of the older deposits. As a rule the sand and gravel are clean and not commingled with clay, and here and there they show false-

bedding. From the inclination or dip of the deposits, and the lie of the gravel-stones, it is evident that they have been laid down by a current of water flowing persistently down the valley, in other words they are true fluviatile accumulations. They prove, therefore, that the sea eventually retreated, and so allowed streams and rivers to plough their way down through the thick sheets of clay, sand, and gravel, which had been spread out by the floods of late glacial times, and had gathered over the floor of the old estuary. They further tell us that the land must have stood at that time at a higher level than it does now, for we find them here and there passing below the present beds of the rivers. How deep they go I cannot say, but various phenomena lead me to believe that their actual thickness cannot be great. Probably the ancient postglacial bed of the Tay does not lie more than a few fathoms below the bottom of the present stream, and thus the old coast-line at the period I refer to may not have stretched much farther out to sea than it does now. But however that may have been, this we do know, that the ancient Earn and Tay ploughed a deep and broad course through the late glacial deposits, which when the sea had retreated must have extended at first as a broad and approximately level plain over all the lower reaches of the two valleys. Through this plain the rivers cut their way to a depth of more than 100 feet, and gradually removed all the material over a course which can hardly be less than two miles in breadth below Bridge of Earn, and is considerably more than that in the Carse of Gowrie. Thus we are not only assured that the land then stood at a somewhat higher level than now; but we are compelled to conclude also that a very long time must have elapsed between the disappearance of the old estuary and the accumulation of the buried forest. For incoherent although the late glacial deposits are, and incapable of resisting the powerful erosion of running-water, yet a prolonged period of time was necessarily required for all the denudation they experienced before the trees of the buried forest began to grow.

As the ancient river-deposits have not as yet yielded any organic remains, the evidence they supply as to climatic conditions is only negative. Thus, they afford no trace of the action of ice, they contain no brick-clays like those of late glacial age, neither do they show any ice-floated stones and boulders. They closely resemble, in fact, the river-deposits of the present day.

4. The next bed in ascending order is the buried forest and peat. It is well exposed at various places in the bluffs of the present rivers, and its position has been further proved by numerous well-borings which show that it is present over a wide area. It rests usually upon the surface of the old river-deposits just described, but sometimes when these are absent we find it overlying directly the red and parti-coloured brick-clays of the late glacial series. Although it may be said to occur approximately at the same level, namely at or about that of mean-tide, it by no means rests upon a perfectly horizontal surface. Thus in some places its bed is flush with the surface of the river at high-tide, as in the Earn opposite Abernethy. In other places down the valley it is covered even at low-tide. Mr. Durham, Newport (Fife), tells me that he has seen it extensively exposed upon the low shores in the neighbourhood of Wormit Bay. He also informs me that in building the jetty at the south end of the unfortunate Tay Bridge the contractors cut through a bed of clay abundantly charged with twigs, leaves, nuts, and other vegetable-remains, and that in founding the piers of the bridge a bed of what the workmen called "peat" was frequently cut through. From the samples shown to him, however, Mr. Durham says it was clearly not peat, but a bluish sandy clay full of vegetable *débris*. The most interesting trace of the old land-surface he had observed was at the Stannergate, about half-way between Dundee and Broughty-Ferry, where a bed of the alluvial clay or silt was seen cropping out from below the gravel of the beach. On digging into the bed abundant remains of plants were exposed, amongst these being the trunk and a large branch of what appeared to be an oak. It was buried in a mass of well-preserved leaves and twigs, and

the clay was plentifully charged with hazel-nuts. In the upper reaches of the Carse-land, as at Bridge of Earn, the peat-bed is a few feet above the surface of the river. Still farther to the west, as opposite Easter Balgour, it reaches six to nine feet above the ordinary level of the Earn; and the same is the case in the valley of the Tay at Perth. In short, it generally rests upon the old alluvia described above, the upper surface of which, as might have been expected, is not horizontal, but has a perceptible slope down the valley.

The peat consists, as I have said, of a mass of vegetable matter, which varies in thickness from a few inches up to three or four feet. In some places it seems to be made up chiefly of reed-like plants and sedges, and occasional mosses, commingled with which are abundant fragments of birch, alder, willow, hazel, and pine. In other places it contains trunks and stools of oak and hazel, with hazel-nuts—the trees being rooted in the subjacent deposits. It is generally highly compressed and readily splits into laminæ, upon the surface of which many small seeds now and again appear. Here and there also Dr. Buchanan White and I have detected the wing-cases of beetles. The twigs, branches, and trunks, are likewise compressed, but are usually in a very good state of preservation, having when freshly broken a reddish tint. The colour of the peat itself is usually a dark brown inclining to black. It strongly recalled to me in general appearance the interglacial lignites of Dürnten and Leffe, but when broken up it had not the same indications of extreme age. As a rule the bed is sharply marked off from the silt and clay which immediately overlie it, but occasionally this is not the case—the peat interosculating to some extent with the lower portions of those deposits. But this appearance quickly terminates upwards, as I shall point out presently. In the brick-clay pit at Friarton, Perth, the peat occurs under a thickness of ten or eleven feet of clay. Lying upon and in the peat-bed at this place, and sometimes partly penetrating the underlying river-sand, occur now and again large trunks of pine (*Pinus sylvestris*) which have much the appearance of having been drifted into their present positions. As showing the condition of those trees, I may mention that the workmen usually cut them up for firewood. I have described elsewhere[1] the discovery in this pit of an ancient "dug-out" canoe of pine which occurred on the same horizon as the trees. It lay upon its bottom underneath the whole thickness of the superjacent clay.[2]

That this peat indicates a former land-surface is abundantly proved by the fact that the old soil upon which it rests is usually more or less full of rootlets. Many of these penetrate to a depth of several feet, and are specially numerous when the pavement of the buried forest happens to be a silt or silty sand. The writer of the Old Statistical Account of the district also states that in sinking wells in the Carse-lands "deers' horns, skulls, and other bones," have frequently been found associated with the buried peat, which is quite in keeping with the view that that bed marks an ancient land-surface. At the same time I think it is probable that many of the logs, branches, and twigs of pine which occur frequently in the peat, or resting upon its surface, have been drifted down the valley by water. The fact that the upper surface of the peat in some places contains lines and layers of silt, and that isolated twigs and branches are sometimes scattered through the lower three or four feet of overlying clay and silt, sufficiently demonstrates that all the materials which go to make up the peat-bed did not grow *in situ*.

The position of the buried forest and peat at and below the present sea-level shows us very clearly that at the time the vegetation was growing the sea must have been much farther off than it is now—in other words, the land stood then at a relatively higher level. We have seen that the ancient river-deposits, upon the surface of which the old trees flourished, tell a similar tale. But it is not only the geological position of the forest-bed, but the character of the trees themselves that imply a former wider extent of land. We can hardly suppose that a dense arboreal vegetation would present itself along the immediate margin of the sea. Such a position would be highly unfavourable, and hence we may conclude that when the trees, whose roots are found at and below the sea-level in the lower reaches of the Carse of Gowrie, were flourishing, the sea-coast must have been at a much greater distance than now—but at what distance it may have been we shall not at present inquire, as that is a question which falls to be considered later on.

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[1] *The Scottish Naturalist*, vol. v. p. 1.

[2] For further particulars of the interesting "buried forest" of the Earn and Tay valleys, see G. Buist's "Geology of the South-east of Perthshire," *Trans. of Highland Society*, vol. vii. p. 17; also Sinclair's *Statistical Account of Scotland*, vol. xvi. p. 556; and Jamieson "On the History of the Last Geological Changes in Scotland," *Quart. Journ. Geol. Soc.*, vol. xxi. p. 184.

As to climatic conditions not much can be said. All the plants hitherto observed in the peat are still indigenous to Scotland, but we may certainly infer that the climate could not have been less genial than it is to-day. As we shall presently see, the probabilities are that it was even more genial, but since this is a conclusion which is only arrived at upon a general review of all the facts relating to the buried forests and submarine peat of the British Islands and the opposite shores of the Continent, we shall leave it to be discussed along with other matters in the sequel.

Confining ourselves, then, to the evidence supplied by the buried forest of the Tay and Earn, we find that we have every reason to believe that the elevation of the land or retreat of the sea, which marked the era immediately succeeding the deposition of the estuarine beds of late glacial times, was equally characteristic of what we may call the Age of Forests. Before those forests had taken possession of the valleys the ancient rivers had ploughed out and removed vast quantities of glacial material, and their alluvial plains formed broad flats overlooked on one or both sides by the bluffs of the old 100-feet terrace. All those wide plains became in time densely wooded—while a thick growth of reed-like plants shot up upon the low alluvial banks of the river. Large pine-trees and groves of birch grew upon the neighbouring hill-slopes, while alder and willow formed a thick copse on the lower and damper flats. At this time man was a native of the land, and in his rude canoes, dug out of great pines, boated up and down in the ancient Tay.

5. Deposits of clay and silt—the so-called Carse-clays—immediately overlie the old forest-bed, and vary from ten or fifteen feet up to fully forty feet in thickness. In a few places the beds which directly cover the buried forest consist of gravel and sand ; these, however, are almost invariably overlaid with thick accumulations of clay, silt, and loam.

The surface of these deposits, which form the greater portion of the Carse of Tay and the flats of the Earn valley, is usually stated to be about 25 or 30 feet above the sea ; but this is rather the minimum than the maximum. Only a small area is under 30 feet ; indeed the mean level between Monorgan and Errol can hardly be less than 32 feet. From the railway to the foot of the Sidlaw Hills, against which the Carse-lands abut, the ground rises with a very gentle gradient, so as to attain a height at the margin of the Carse of not less than 45 feet. Thus a wide district between Errol and the Braes of Gowrie averages more than 40 feet above the sea. The boundary of the Carse, followed along the foot of the hills from Longforgan up to and even beyond Perth, is as near as may be horizontal and persistently 45 feet in height. Above Perth it gradually merges with old river-terraces of silt, sand, gravel, and shingle. The wide flats in the lower reaches of the Earn valley are merely a continuation of those of the Carse of Gowrie, with which they correspond precisely in elevation. A considerable part of the flats of the Earn, like much of the Carse of Gowrie, does not average more than 32 feet above sea-level, but in many places it exceeds 40 feet. The upper margin of the Earn flats is also approximately horizontal, and continues at an elevation of 45 feet as far inland as Dalreoch, beyond which it shortly passes into true river-alluvia.

Such facts suffice to show that these upper deposits of the Carse are of estuarine origin, and their connection with a former lower level of the land, and consequent incursion of the sea, is demonstrated by the appearance of marine shells in the clays.

These, however, appear to be restricted to the lower reaches of the Carse of Gowrie. Thus Mr. Jamieson mentions the occurrence of *Scrobicularia piperata* in the silt and clay which overlie the old buried forest at Polgavie ; and I have seen quantities of the same shell turned up during the digging of a deep drain in the Carse near Inchture. But I have not observed any marine organic remains in the Carse-clays farther up the valley,[1] although there appears no reason why sea-shells should not occur now and then as far up the valley at least as Glencarse. There are, however, comparatively few good exposures, and the shells, for various reasons, were probably never very abundantly distributed through the deposits. When they do occur, it is usually in thin, lenticular beds, which seem to be quite local, so that, in the absence of deep cuttings and continuous sections, our chances of coming upon such isolated patches are small.

I have mentioned the fact that when the Carse-clays are followed up the valleys, they eventually pass into true river-deposits. The same we have seen is the case with the clays of the 100-feet terrace. The true Carse-beds, however, differ in many respects from these older estuarine accumulations. Thus they as a rule contain no scattered stones and boulders, and are not generally true clays, but rather silts. But although this is their usual character, yet they are not so entirely stoneless as some geologists have stated them to be. Here and there I have detected small stones embedded in the fine silt and clay, some of which measured as much as 6 inches across ; and occasionally I have met with angular boulders a foot and more in diameter. The largest block I have noticed was one which measured 4 feet across. But stones and boulders of any kind are certainly quite exceptional. Now and again the deposits consist of tough, tenacious brick-clay, which does not differ in appearance from similar brick-clays of glacial age. Their general colour is a dull brown or dirty gray; in some places inclining to pale yellowish gray, and grayish blue.

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[1] Mention is made in Sinclair's *Statistical Account*, vol. xvi. p. 555, of the frequent recurrence in the Carse-clay of "sea-shells," but no special localities are given. A polished stone implement is also said to have been found at Errol along with shells.

Taking all these facts into consideration, we arrive at the conclusion that the Carse-clays are estuarine deposits, and were accumulated at a time when the Firth of Tay reached considerably farther inland than it does now. The upper margin of the Carse-clays represents the old water-level, which stood then 45 feet above the present mean-tide. After the ancient forests had flourished for a long period, the sea began slowly to gain upon the land, and the ancient Earn and Tay, which, during the age of forest-growth, were probably streams of no greater size, and perhaps were even smaller than the present rivers, acquired a larger volume, and commenced to overflow the low-lying tree-covered plains. Sheets of gravel and sand, and alluvial silt and mud, were thus gradually spread over the site of the ancient forests; while in some places all relics of the old land-surface were swept away. The torrential character which the rivers assumed at this time is shown by the masses of coarse shingle which they carried along. The trees which grew close to the water were often undermined, and, falling into the streams, were floated away down the valley. Ere long, however, the lower reaches of the valleys were converted into a broad estuary, and the destruction of the forest-bed in those regions was arrested. The muddy rivers still continued to flow with undiminished volume, but the coarser sediment they swept along was arrested soon after it entered the estuary—only the finer mud being carried farther, and distributed over the whole wide surface of the drowned low grounds.

The presence of the isolated stones and boulders which occur at rare intervals in the Carse-clays shows that floating-ice was not unknown at this late period. The stones may have been frozen into shore-ice, forming in winter along the margins of the estuary, or they may have been carried down by river-ice. The largest boulder I have observed, however, hardly could have been derived from any region north of Perth. It is a fragment of porphyrite of precisely the same character as the rock of

Kinnoul Hill and that neighbourhood.[1] However that may be, it is evident that the ice which lifted and floated off a boulder measuring 4 feet in diameter must have been of considerable thickness. Nevertheless, the mere occurrence of those few sporadic erratics can hardly be appealed to as conclusive evidence of colder climatic conditions than now obtain. During the winter of 1878-79 I saw ground-ice forming rapidly on the bed of the Tay at Perth ; and shortly afterwards the river, which is tidal at that place, was frozen over to a depth of 12 and 14 inches. When the ice broke up and floated away, it must have carried seaward a goodly number of small erratics, for I noticed gravel-stones in several blocks of ice which were stranded on the banks opposite Kinfauns. It is rather the general character of the Carse-deposits themselves than the presence in these of a few sporadic erratics which appears to indicate colder climatic conditions. The fine, tenacious brick-clays, and even the less cohesive silty or loamy clays, cannot be likened to the dark sludge and slimy silt and mud which are now gathering upon the estuarine bed of the Tay, but they closely resemble, and even in many cases are identical in character with, those laminated clays of true glacial age which contain Arctic shells. The rivers which flowed into the ancient estuary of the Tay at the time the Carse-beds were forming appear to have been abundantly charged with finely-levigated matter. They must have been, in short, extremely muddy rivers ; and some idea of the quantity of material they carried in suspension may be gathered from the fact that the Carse-clays cover an area of not less than 35 square miles, to a depth varying from 10 to 40 feet and more. And to this we must add also the material which was swept out to the open sea, as well as the great loss by denudation which the clays have experienced since the sea finally retreated to its present level.

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[1] Porphyrites occur also along the foot of the Grampians, near Dunkeld ; and it is just possible that the boulder in question may have been drifted by ice down the ancient Tay from that neighbourhood.

It is in keeping with the evidence furnished by the Carse-clays that the ancient river-terraces into which they pass as they are followed inland, should betoken a much larger volume for the rivers than these now attain. Not only did they formerly overflow a broader area, but, despite the fact that their course was at that time considerably shorter than now, they yet often had quite a torrential character. This is seen in those broad stretches of high-level sand, gravel, and shingle, with their frequent tumultuous bedding, which extend over wide areas in the upper reaches of the Tay above Stanley, and in the Earn above Dalreoch.

These appearances, taken in connection with the character of the true Carse-deposits, seem to me to point to a period of greater rainfall than the present, and also to a lower winter-temperature. The Carse-clays I consider to be in large measure made up of the fine "flour of rocks" derived from the grinding action of glaciers which then occupied the mountain-valleys of the Highlands, and from which muddy water escaped in large quantities, especially during summer. The melting of the snow and ice, and the more or less sudden disengagement in the warm season of great bodies of water, account very well for the wide-spread and thick deposits of sand, gravel, and shingle which occur in the upper reaches of the valleys. Receiving the tribute of so many swollen glacial streams and rivers, the estuary of the Tay, we may well suppose, would be considerably freshened in its upper reaches; and the conditions at and for some distance below Perth might thus be quite unfavourable to marine life. It is perhaps for this reason that sea-shells appear to be absent from that part of the old sea-bottom.

I am thus led to believe that the accumulation of our Carse-clays coincided with a period of local glaciation in our mountain-valleys—a view which we shall presently see is supported by another line of evidence.

6. The deposits next in succession consist of river-gravel, sand, and silt, which form terraces along one or both sides of the present rivers. They point to a time when the sea gradually

retired from the district to its present level. During its retreat the streams and rivers busied themselves with excavating the old estuarine deposits, and as they worked their way down to lower levels, benches and terraces of alluvial matter were left behind to mark the positions they successively occupied.

If now we pass to the valley of the Forth, we shall there meet with a similar succession of changes. The late glacial deposits of the Forth form what is known as the 100-feet terrace. Near Falkirk, the upper limits of this terrace are marked out by the 100-feet contour line, but as we trace the deposits up the valley they gradually rise to higher levels, until at last they pass into ancient river-gravels. Within this great terrace, and separated from it by a steep bluff or cliff, lies a second extensive flat, the upper margin of which coincides nearly with the 50-feet contour line. This is the well-known Carse. The deposits of which it is composed consist principally of mud, silt, clay, and sand, with beds of recent sea-shells, such as *Cardium edule, Ostrea edulis, Mytilus edulis, Cyprina islandica, Littorina litorea, Trophon clathratus, Buccinum undatum,* etc. This wide marine flat, according to Mr. B. N. Peach, is "in great measure a platform cut out of the older drift deposits; and in some places, indeed, projecting ridges of the underlying rock have been reached."[1] Layers of peat and much drifted vegetable-matter, consisting of trunks, branches, and twigs of trees (birch, hazel, pine, oak), occur at various levels in the Carse-deposits. But none of the peat-beds, Mr. Peach tells me, indicates an old land-surface. In some of the peat-beds, which are made up of matted and tangled masses of sticks, twigs and branches of trees, oyster-shells occur in abundance, as in a peat-bed near Bridge of Allan. Remains of the whale,[2] canoes,[3] and rude weapons and implements have also been discovered, sometimes at considerable depths in the Carse-deposits. It is extremely interesting to learn that old refuse-heaps or kitchen-middens appear frequently along the inner margin of the Carse. "All the middens observed," Mr. Peach says, "occur on the bluff itself or just at its base, as if, when it was the limit of high-water, the people who formed the middens, after searching the shores during low-water, had retreated thither to enjoy their feast while the tide covered their hunting-ground." Remains of fireplaces are plentiful among the shell-heaps.

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[1] *Memoirs of the Geol. Survey, Scotland,* Expl. of Sheet 31 (One-inch Map), p. 54.

[2] For accounts of whale-remains got in Carse of Forth, see *Edinburgh Philosophical Journal,* vol. i. p. 395; vol. xi. pp. 220, 415; *Transactions of the Wernerian Society,* vol. iii. p. 327; vol. v. pp. 437, 440.

[3] *Bibliotheca Topog. Britan.,* No. II., Part iii. p. 242; *Beauties of Scotland,* vol. iii. p. 419; *Bot. Nat. Hist. Soc. Glasgow,* vol. i. p. 168; ii. p. 65; *Geological Magazine,* vol. vi. p. 37; *Brit. Ass. Rep.,* vol. xxiv. p. 80.

When the Carse-beds are followed up the valley, they are found rising with a gentle gradient, until eventually they pass into freshwater alluvial deposits of fluviatile origin. Followed down the valley to the shores of the present estuary, the level of the Carse-land falls more or less gradually away to a height of 25 or 30 feet, and still lower terraces succeed down to the most recent alluvium. All these later platforms have evidently been eroded in the estuarine-marine deposits of the Carse—partly by the waters of the estuary itself when they stood at a higher level than at present, and partly by the river Forth and its tributaries during and after the final retreat of the sea.

Thus in the wide valley of the Forth we have simply a repetition of the phenomena which are presented by the late glacial and postglacial deposits of the Tay and the Earn. After the accumulation of the late glacial beds of the 100-feet terrace, the sea disappeared from the district of Stirling and Falkirk, and left a broad platform of clay and sand exposed to the action of streams and rivers. Owing to the great thickness attained by the Carse-deposits of the Forth, it is not often that the junction between these and the glacial beds can be seen. But along the upper margin of the 50-feet terrace the Carse-beds, which thin off upon the ancient beach, can be observed resting directly upon true glacial deposits. No old river-gravels and overlying forest-bed, such as those of the Tay and Earn, have yet been detected occupying a similar position between the Carse-clays and the glacial deposits of the Forth. But that similar stages did exist may be reasonably inferred. The 100-feet terrace must first have been eroded, and a wide, broad trough scooped out of it, before the overlying Carse-clays could have been laid down; and it is unlikely that this erosion was the work of the sea. The sea in which the Carse-clay was deposited simply occupied an old land-valley, the bottom of which it levelled up with silt and clay, while at the same time it cut back the glacial deposits that formed its margin. Although no ancient land-surface or forest-bed is known to occur at the bottom of the Carse-clays, it is not unlikely that such a buried forest does nevertheless exist. The character of the old valley which lies concealed is very imperfectly known to us, for it is only in a few places where its surface has been reached, and it may quite well be that considerable remains of forest-vegetation occupying the place of growth, may be buried under the great Carse-lands of the Forth. We know, at all events, that a submarine peat with tree-remains occurs at Largo, on the shores of Fife, resting upon glacial deposits and evidently of older date than the recent raised-beach of that neighbourhood. Be that, however, as it may, the Carse-deposits of the Forth contain frequent intercalated layers of tree-remains and sporadic logs and snags, all of which point to the fact that an arboreal vegetation, similar to that which now covers the country, clothed the hill-slopes and valley-bottoms at the time the Carse-clays began to be laid down. A great change of climate must therefore have supervened after the close of the Glacial Period and before the Carse-clays were accumulated. Not only had the sea retreated and the land acquired a larger area, but the arctic cold had been succeeded by genial climatic conditions which induced a luxuriant forest-vegetation.

The shells of the Carse-beds are all of recent British species, but the presence of the whale, which belongs to the large Greenland species, may possibly indicate a somewhat colder climate than the present. And this indication derives greater force from the fact that the Carse-beds, when they are followed up the valley, gradually merge with extensive river-deposits, the character and extent of which demand the former flow of a much greater body of water than now circulates in the Forth and its tributaries. In short, these gravels and sands have the same appearance as those of the Earn and the Tay, and seem to me to point to the same conditions. The valleys were then liable to be greatly flooded, owing to the more or less sudden melting of the snow in the higher districts. In spring and autumn volumes of muddy water descended to the estuary, bearing with them ever and anon whole rafts of uprooted trees, which, getting water-logged, would sink to the bottom, or now and again run aground upon mud-banks and shoals, where in time they would become entombed in the gradually accumulating sediment. At this period Neolithic man inhabited Scotland, living along the shores of the broad estuary, where he subsisted to a large extent upon shell-fish. Occasionally he succeeded in capturing the whale, skeletons of which have been found along the margin of the ancient Forth associated with primitive implements of stone and horn. The remains of man himself, however, have rarely been met with in the Carse-clays. In the year 1843, while some alterations were being made upon the canal at Grangemouth, a human skull (dolichocephalic) was discovered at a depth of 21 feet below the surface. But so far as I know this is quite exceptional. Probably the old whale-hunters and shell-gatherers were good weather-prophets, and never trusted themselves far from land when there was any prospect of a storm. Most of the canoes which have been found may have been drifted from their moorings, or if they capsized with their owners on board, the land was probably near enough to be reached by swimming.

Eventually the sea, which had attained to a height above its present level of about 50 feet, began again to retire, until ere long it had receded to a vertical distance of 25 or 30 feet, and thus left exposed a broad expanse of low-lying alluvial grounds in the upper reaches of the estuary. We have no means of measuring the time required for this change, but it probably implies the lapse of many centuries. At all events we know that when the sea-level had fallen to that of the 25-30-feet beach, weapons, implements, and ornaments of bronze, had come into use among the natives of Scotland. Probably, also, the climate had become milder, for in none of the most recent raised-beaches (25-30 feet) do we find the slightest indications of a colder temperature than the present. The last elevation of the land or retreat of the sea in Scotland took place long after the knowledge of metals had been introduced.

My friend Dr. Howden of Montrose has given a very interesting description of the postglacial deposits in the neighbourhood of that town,[1] which agree in all essential points with the similar accumulations in the valleys of the Tay and the Forth. The succession given by Dr. Howden may be briefly summarised as follows—the beds being named in descending order :—

1. Alluvial Carse-clay and *Scrobicularia*-silt.
2. Peat-bed.
3. Laminated clay with arctic shells.

The laminated clay belongs to the late glacial series, and has yielded a number of shells and other organisms of arctic types—such as *Cyprina islandica, Pecten grœnlandicus, Leda arctica, Yoldia pygmæa,* etc. The peat-bed is nowhere exposed at the surface, but has been reached in borings and artificial cuttings. At Montrose Gasworks it was found under 20 feet of estuary-mud and sand, the greater part of the section being below the level of the sea. "It rested almost directly upon the glacial marine clay, and contained stems of trees, leaves of bog-plants, and numerous seeds, mostly resembling those of some *Juncus*." In addition to these Dr. Howden obtained also "a single seed of a cereal, to all appearance the common barley (*Hordeum distichum*)." The same observer informs us that fragments of peat containing a great many elytra of beetles were found in the sand at a depth of 20 feet below the surface during the construction of a new dock at Montrose. Above the peat-bed at the Gasworks the deposits were of true estuarine character, and contained many estuarine shells. The Carse-clay

[1] *Trans. Geol. Soc. Edin.*, vol. i. p. 138.

in its upper part contains no shells, but it rests upon and in places seems to graduate into the fossiliferous estuarine mud and sand. In a section recently exposed at a few feet above high-tide mark in a railway cutting at Montrose, which I visited in company with Dr. Howden, the Carse-clay is a pale yellowish-gray deposit, destitute of fossils, and having all the appearance of a freshwater accumulation. It rested directly upon a dark grayish-blue silt and mud, which is charged with marine shells, and from which a skull of the long-fronted ox (*Bos longifrons*) was obtained. The contrast in colour and consistency between the true Carse-clay and the underlying *Scrobicularia*-silt was very marked.

The succession of changes evinced by these accumulations appears to be as follows :—

1*st*, Long after the retreat of the glacial sea, the land extended considerably farther out to sea than it now does, and the climatic conditions were certainly not less genial than they are at present—an arboreal vegetation clothing the country.

2*d*, A period of submergence ensued when the sea advanced inland beyond its present limits, and reached to a height of not less than 20 feet and probably as much as 45 feet above its present level. *Scrobicularia piperata* and other shells then flourished in abundance in what are now the lower reaches of the river Esk.

3*d*, The Esk by and by carried down immense quantities of fine gray and yellow silt, with which it choked up the estuary—the upper reaches of which would be greatly freshened by the abundant influx of river-water. It is for these reasons that the Carse-clays in the upper part of the old estuary are, as Dr. Howden has shown, unfossiliferous. The phenomena indicate, as it seems to me, conditions quite analogous to those presented by the Carse-deposits of the Tay. Local glaciers then occupied the Highland valleys, and discharged large volumes of muddy water during summer.

4*th*, Elevation of the land now ensued, and the sea retreated to lower and lower levels, until eventually the coast extended farther into the North Sea than is now the case. [Probably this stage was synchronous with the reappearance of a vigorous forest-growth in the lower reaches of our great estuaries.]

5th, The sea again advanced and cut back into the Montrose basin, upon the margin of which we now find low bluffs formed of the old *Scrobicularia*-silt and the overlying estuarine or brackish-water Carse-clay.

Such then is a brief outline of the successive changes which took place in the valleys of the Tay, the Forth, and the South Esk in Postglacial and Recent times. That these mutations were not merely local but characteristic of a much wider area is proved by copious evidence. The buried land-surfaces of the Tay and the South Esk have their counterparts in the so-called submarine forests and peat which occur at many different places all round the shores of Scotland,[1] and similar submerged land-surfaces are common upon the coasts of England and Ireland. The position of most of the Scottish "submarine forests" is clearly at or near the base of the true postglacial series. They rest upon various members of the glacial series—sometimes upon boulder-clay, at other times upon the sands and clays pertaining to the close of the Glacial Period. Thus they demonstrate that after the disappearance of glacial conditions the sea retired from all the low grounds of Scotland, and the land acquired a considerably wider area than it now possesses. They further show that the climate at the time of their growth could not have been less genial than it is at present; indeed, as I shall endeavour to prove, the climate must actually have been considerably milder than it is now. The occurrence of an ancient dug-out canoe in the buried forest-bed of the Tay valley is the only positive and direct evidence we have that man was an occupant of Scotland in early postglacial times—that is to say, in times anterior to the formation of the Carse-clays and the raised-beach of 45-50 feet. It is highly probable, however, that the buried trees which occur at the bottom of some of the deepest and oldest peat-bogs of the inland districts are synchronous with those which underlie the Carse-deposits, and human relics, as is well known, have from time to time been found associated with the former. But as trees and peat-forming mosses have been growing and accumulating in Scotland ever since the earliest invasion of the Germanic flora, it must always be extremely difficult to ascertain the exact position in the postglacial series of any particular peat-bed and buried forest. All we can say is simply this, that the lower portions of the thicker peat-bogs, with their included trees, date probably back to early postglacial times, while their upper parts must belong to a later and often to a very recent date indeed.

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[1] For descriptions of Scottish submarine forests and peat, see *Edinburgh Philosophical Journal*, vol. iii. p. 100 ; vol. vii. p. 125 ; Sinclair's *Statistical Account of Scotland*, vols. vii. p. 451 ; x. p. 373 ; xiii. p. 321 ; xvi. p. 556 ; *New Statistical Account of Scotland*, vol. i. pp. 16, 243 ; *Trans. Royal Soc. Edin.*, vols. ix. p. 419 ; xxiv. p. 363 ; *Quarterly Journal of Science, Literature, and Art*, vol. xxix. p. 21 ; *Mem. Wernerian Soc.*, vol. v. pp. 24, 440 ; *Trans. Highland Soc.*, vol. vii. (1841) p. 17 ; *Quart. Journ. Geol. Soc.*, 1865, p. 183 ; 1867, p. 196 ; Anderson's *Practical Treatise on Peat-Moss*, p. 150 ; Barry's *Orkney Islands*, p. 282 ; Miller's *Sketch-book of Geology*. p. 321 ; and *Edinburgh and its Neighbourhood*, p. 91 ; *Journal of Botany*, vol. v. (1867), p. 174 ; *Trans. Bot. Soc. Edin.*, vol. ix. (1868), p. 146 ; *The Great Ice Age*, 2d ed., p. 307.

CHAPTER XVII.

POSTGLACIAL AND RECENT DEPOSITS OF THE BRITISH ISLANDS—*Continued.*

Larger size of Scottish rivers in Postglacial times—Local glaciers then reached the sea-level—Recent glaciation in mountain-valleys of Scotland—Contrasts between glacial phenomena of the Ice Age and Postglacial times—Examples of postglacial moraines—Interval between the close of the Glacial Period and the reappearance of local glaciers in Postglacial Period—Scottish raised-beaches—Peat-bogs of inland districts—Buried forests in peat-bogs—Correlation of these with the submarine forests and peat of the maritime districts—Age of the Scottish peat-bogs—Alluvial deposits of Scotland—Their organic remains—Correlation of archæological epochs with geological stages in Postglacial history of Scotland.

THE rivers of Scotland, as I have said, flowed during a certain stage of the Postglacial Period in deeper volume than at present, a conclusion which is based partly upon the coarse and tumultuous character of their gravels, and partly upon the fact that their flood-loams cover much wider areas and reach to much higher levels than any similar deposits pertaining to the rivers of more recent times. If one wished to compare the work done by the rivers of our own day with that which the same streams were capable of accomplishing in postglacial times, he would do well to trace some such river as the Tweed, the Tay, or the Clyde, from its source to its mouth. He would note that, even in the upper reaches of the river and its tributaries, the valley-bottoms often show old water-levels at heights to which the streams cannot now attain. These old levels are composed for the most part of coarse gravel and shingle, with now and again many large boulders, confusedly arranged for the most part, and betokening the action of more or less torrential water. At the time those gravel-banks were being formed the streams must not only have been deeper but broader than at present, seeing that the modern alluvial flats consist generally of more orderly arranged materials, which are flanked on one or both sides by the truncated ends of the older deposits. In short, we have here the very common phenomenon of "valley within valley." The accompanying diagrammatic section will show more clearly what is meant. Resting upon the rocky bottom of the valley is a layer of till, *t*, with overlying glacial gravels, *g*, the presence of which proves that the valley was in existence before the Glacial Period. Upon the denuded surface of the till and glacial gravel comes a succession of terraces, all of which have been formed in Postglacial and Recent times. The highest of these (1) is of course the oldest of the series—it may be 10 or 15 feet, or even more, above the level of the present stream. It points to a time when the river was able to flood the whole bottom of the valley from side to side. At a lower level a second terrace (2) appears. As this terrace occurs within the former one, it proves that the river eventually became reduced in volume, and, no longer able to flood the whole valley, proceeded to cut for itself a channel through its own deposits. The third and lowest terrace represents the surface which the stream in our own day covers during flood. Its diminished width and lower level indicate a further reduction in the volume of water. I do not of course mean to say that all those alluvial terraces, which are now just beyond the reach of rivers in flood, were formed at a time when those rivers were deeper and broader.

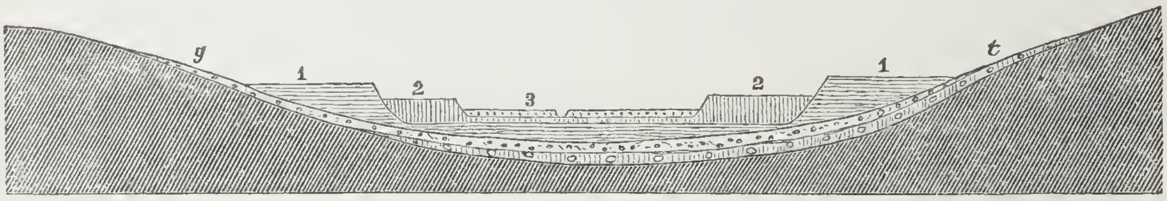

Fig. 12.—Diagrammatic Section of Postglacial and Recent River-gravels, etc. *t*, till; *g*, glacial gravels; 1, 2, 3, successive terraces of alluvial origin.

Every one knows that while with each flood a stream adds by new deposition to the height of its flood-plain, it continues at the same time to excavate the bed in which it flows, so that by and by, when its channel is sufficiently deepened, some portions of the alluvial flats cease to be subject to floods. But the river sooner or later undermines these heightened terraces, as it winds about, and is ever forming newer flats at lower levels. And should it continue to flow with the same volume and under the same conditions, the newer flats would eventually come to occupy as broad a space as that formerly covered by the older terraces, the latter in fact would be entirely demolished. The fact that the high-level postglacial terraces have not been denuded away, but still in many places form more or less continuous plains on one or both sides of a valley, sufficiently proves that the streams had formerly a much larger sectional area. And the generally coarser character of the older river-deposits is in complete accord with this view.[1]

As we follow the rivers down to the lowlands we shall find the contrast between the modern alluvial flats and the older terraces becoming more and more pronounced. The former have clearly been excavated out of the latter. So extensively and approximately level are many of the more ancient terraces that they have frequently been described as old sea-beaches, notwithstanding that they are manifestly related to the river valleys, that the carry of the gravel-stones is invariably *down* the valleys, that the arrangement of the stones and the character of the bedding point to the passage of a current of water continuously in the same direction, and that while the deposits have now and then yielded remains of land-plants and molluscs, mammals, and fluviatile shells, they have never disclosed a single trace of any marine organism whatever. It is only when we come down to low levels—to heights of 50 feet or so above the sea—that the old river-terraces merge with estuarine flats, in the lower reaches of which sea-shells now and then make their appearance.

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[1] The geological reader will understand that the relative levels of the inland- and mountain-districts are assumed to have remained practically unchanged since glacial times. There is not the slightest evidence to show that the inland or hilly districts, during the Glacial Period, stood at a higher or lower level relatively to the surrounding low grounds than they do now. Such oscillations of sea-level as are proved to have taken place in Postglacial times appear to have affected the country *en masse*, although there are good grounds for believing that in the extreme north of Scotland there has been a recent submergence which does not seem to have extended far to the south.

Other writers, again, have maintained that the old river-terraces of certain lowland-valleys, such as those of the Clyde between Nethanfoot and Bothwell, were the beds of ancient lakes. In that district the Clyde flows through a succession of open flat-bottomed spaces, which are connected by comparatively narrow passages. The opener parts of the valley are supposed to have been occupied by lakes which were subsequently drained by the cutting through of the somewhat contracted outlets which now serve for a course to the river. This, however, has certainly not been the case. The valley as we see it, broad flats and narrower passages alike, is entirely the work of the stream and subaerial agents generally. The river flows partly in a preglacial and partly in a postglacial course. The wider reaches correspond with the former, and the narrower portions with the latter. In the one section of its course it had to deal only with more or less incoherent glacial deposits which were easily demolished ; in the other it had to force a way down through massive strata of sandstone and shale. Hence the width of the valley has been determined by the nature of the materials which had to be removed. Where these were soft and easily undermined and washed away the valley has attained a goodly width ; where they yielded less readily to denudation the river has been forced to content itself with a narrower course. In postglacial times, when the rainfall was greater, the Clyde had little difficulty in flooding the wider reaches of its valley, which during spates would appear as a series of temporary lakes connected by broad channels of torrential water.

If the submarine forests prove that Scotland in early postglacial times was of larger extent and enjoyed a genial climate, the old estuarine deposits of the Tay, the Forth, the Clyde, and other rivers, and the raised-beaches of the more open coasts, demonstrate a subsequent general submergence of the land to a depth below its present level of about 50 feet; and they likewise afford more or less striking indications of a climatic change from genial to less genial conditions. I have given my reasons for believing that much of the clay in the older Carse-deposits is of glacial origin, and consists of the fine mud and silt carried down by turbid rivers, the upper reaches of whose valleys were occupied by local glaciers. This, however, is not the only evidence we have of glacial action at the time the sea stood at the 45-50-feet level. In many of the Highland sea-lochs glaciers would appear to have come down to the sea and calved their icebergs there; and this is probably the reason why the 45-50-feet beach is not often well seen at the heads of such sea-lochs. The glaciers seem in many cases to have flowed on for some distance into the sea, and so prevented the formation of a beach and cliff-line. In other cases, however, they appear to have thrown down their moraines as soon as they reached the sea. A very good example of this occurs at the mouth of Glen Brora in Sutherland, where well-marked moraines and morainic gravel with large blocks are found resting upon and apparently of the same age as the deposits of the raised-beach. When the Highland valleys of the west coast come to be examined more attentively by geologists, I have no doubt that similar appearances will be discovered in many places. The moraines of the old glacier of Glen Messan (Argyleshire), described long ago by Charles Maclaren,[1] come down to within 40 feet or less of the present sea-level, and, according to Robert Chambers,[2] morainic detritus rests upon the 30-feet beach at the opening of Glen Iorsa in Arran.

The general fresh appearance of *roches moutonnées* and striæ in many Highland glens, and the fine state of preservation of the valley-moraines, have often been adduced as proof that the

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[1] *Brit. Assoc. Rep.*, 1850, p. 90; *Edin. New Phil. Journal*, New Series, 1855, vol. i. p. 189.

[2] *Brit. Assoc. Rep.*, 1854, Trans. of Sections, p. 78; *Edin. New Phil. Jour.*, New Series, vol. i. p. 103.

Glacial Period of geologists cannot be of such extreme antiquity as is commonly believed. But this objection disappears when we learn that local glaciers occupied those mountain-valleys in Postglacial times, and descended in many cases to the sea-level at a time when Neolithic man was an occupant of the country. From certain evidence met with both in the Southern Uplands and Northern Highlands, the advent of these later local glaciers would seem to have been preceded by a period during which the snow-fields and glaciers of the previous Ice Age had either vanished or become greatly attenuated. It is frequently impossible, however, to distinguish between the morainic *débris* of late glacial and the moraines of postglacial times. The glaciers of the latter period appear in some cases to have ploughed out the boulder-clay of the Ice Age proper, so that their moraines often rest directly upon the rocky pavement of the valleys. But this of itself can hardly be taken as a proof of the postglacial age of those glaciers, for, during the retreat of the local glaciers towards the close of the true Glacial Period, the older drifts would be liable to the same kind of erosion. It is rather from the general appearance of freshness presented by the local moraine-mounds of postglacial age that their more recent date can be inferred. Let me give an example or two of the appearances I refer to. In the neighbourhood of Loch Skene in Peeblesshire is a group of finely-preserved moraines, which have been described in detail by Professor Young.[1] They are strictly local and confined to the heads of certain valleys, some of which drain into the Moffat and Yarrow waters, while others are tributary to the river Tweed. So fresh and beautifully preserved are the mounds and cones that it is difficult to believe that they can date back to a period so vastly remote as the Ice Age is believed to be. Now all the valleys leading down from the heights above Loch Skene are sprinkled with morainic *débris*, gravel, and boulder-clay, which may be followed down into the main valleys and across the low grounds to the sea. These deposits are the *débris* accumulated and frequently re-arranged during the Glacial Period proper. I have in a former chapter described the closing scenes of the true Ice Age, and shown that the *mer de glace* melted away from the low grounds, breaking up as it were into a series of large local glaciers, which gradually shrank up the valleys. The morainic *débris* and perched blocks dropped by these glaciers can still be followed along the slopes of the valleys in Peeblesshire, but no well-defined morainic mounds now occupy the valley-bottoms at low levels. If such ever did exist, they have all been swept away by the denuding action of torrents, streams, and rivers. It is only when we reach the very heads of the upper valleys, as in those of the Manor, the Talla, the Fruid, and other streams, that we encounter well-marked conspicuous mounds of morainic matter.

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[1] *Quart. Jour. Geol. Soc.*, 1864, p. 452.

Similar examples of isolated and well-preserved moraines occur in the Cheviots, and they are especially numerous in the mountain-valleys of South Ayrshire, Kirkcudbright, and Wigton. In the Northern Highlands there is hardly a high valley in which they may not be seen, and the distinction between the shapely cones and ridges of the recent moraines and the denuded heaps of morainic *débris* and great banks of gravel which marked the dissolution of the older glaciers, is always more or less well defined. As an excellent example, and one of easy access, I may point to Glen Turret, in the neighbourhood of Crieff, at the head of which morainic cones and ridges are abundant and beautifully preserved. Farther down the valley, below the lake, the only relics of the older glaciation are weathered *roches moutonnées*, scattered angular boulders, degraded morainic mounds, boulder-clay, and diluvial sand and gravel.

It has been held by some geologists that the reason why moraines are so well preserved and prominent in the upper reaches of many mountain-valleys, may be due to the glaciers of the Ice Age having made a long pause in those localities before they finally disappeared. They suppose that the great glaciers melted slowly but continuously away from the lower reaches of the valleys, so as never to allow of the accumulation of distinct frontal moraines until they were just about to vanish for ever.

But this, as we know, was not the case, for frontal moraines of considerable size, although usually much worn and degraded, do now and then occur at or near the mouths of many of the more considerable mountain-valleys ; and the whole evidence would lead me to conclude that the glaciers of late glacial times took a very long time indeed to melt away, so as to allow of the accumulation of great heaps of angular *débris* and morainic gravels. Thus at the opening of the mountain-reaches of the Tay valley below Dunkeld we encounter abundant heaps and hummocks of morainic gravel, shingle, and boulders, which are merely highly denuded frontal moraines, the general concentric arrangement of which can yet be traced and mapped out. And similar morainic gravels are noticeable at many other places farther up the valley. It is not until we get to the heads of the glens above Loch Tay that we encounter moraines which bear every mark of a more recent origin. Now, did these well-preserved moraines really pertain to the Glacial Period properly so called, I should have expected to trace a gradual passage between them and the more worn and wasted morainic heaps farther down the valleys. Why, in walking up a long Highland glen, should we almost invariably pass at once from highly-wasted and denuded banks and heaps of morainic detritus to a series of cones and ridges sprinkled with perched blocks, which look so fresh that the glaciers which deposited them might have occupied the upper valley-reaches only a few years ago? There are two answers which may be given to this query. It might be held that the new-looking fresh moraines in the upper reaches of the glens were deposited during the last stand made by the glaciers at the closing period of the Ice Age; the more perfect appearance of the cones and ridges being accounted for, partly by the fact that they were the last to be laid down, and partly also by supposing that the attenuated glaciers which heaped them up made a considerable pause at the heads of the glens before they finally melted away. But while it may be admitted that the moraines which were last to be deposited would necessarily show less signs of age than those belonging to the time when the glaciers occupied the longest Highland valleys throughout their entire extent, yet this does not help us to explain the great contrast in point of preservation which obtains between the two series. The latest moraines are evidently of much more recent origin than the more or less degraded moraines which are met with in the lower reaches of the same valleys.

Are we to believe, then, that the glaciers of the old Ice Age continued to hold their own from the close of that period down to the time when the Carse-clays were deposited? This in itself is highly improbable, as I shall point out afterwards, when we come to sum up all the evidence bearing upon the question of postglacial climate, but for the present the improbability of the hypothesis is rendered sufficiently obvious by the small size of the moraines in question. If local glaciers occupied the upper reaches of the longer valleys of the Highlands and Southern Uplands from the close of the Glacial Period down through that of the "buried trees" and "submarine peat," and on to the time when Carse-clays were deposited and Neolithic man occupied Scotland, we might surely have looked for very much larger moraines in place of the small cones and ridges which actually occur. The more reasonable explanation of the phenomena appears to be that which infers that after the final dissolution of the glaciers at the close of the Glacial Period, perennial snow and ice either disappeared entirely for a time or were reduced to very insignificant patches, and that, at a subsequent period, they again increased, and local glaciers, sometimes attaining a considerable size, once more occupied the mountain-valleys, and deposited a newer series of moraines. Nor is this explanation based simply upon the fresher appearance and generally smaller size of these moraines, as compared with the often much-worn and older aspect of the more widely-spread erratic detritus at lower reaches in the same valleys. Now and again one may notice how the latest local glaciers have partially overridden the heaps of *débris* which had gathered in the valleys after the disappearance of the glaciers of the last cold stage of the true Glacial Period, while in other cases they have even been deflected by masses of rock which, falling in late glacial and early postglacial times, had choked up the paths followed by the ice of the true Ice Age. The presence of such a "bergfall" has even been adduced as proof that the glaciers of the Ice Age had little power to scoop and erode, seeing that the fallen rock-masses have not only not been removed by the local glaciers, but have even sufficed to control the direction in which these latter flowed. Thus a writer in *Nature*[1] has called attention to the large "bergfall" of sandstone which cumbers the bottom of Glen Beansdale at Loch Maree, and which has forced the stream out of its old course, and compelled it to dig for itself a new passage between the bergfall and the opposite slopes of the valley. This newer course, after having been formed by the stream, was at a later date traversed by a local glacier which necessarily flowed in the same direction, the old stream-course being effectually blocked up by the great fall of sandstone from the cliffs at the base of which the water formerly ran down to Loch Maree. The writer concludes that this bergfall is of preglacial age; and from the fact that it looks so fresh that it "might have fallen within the memory of man, instead of at a date which must be reckoned by thousands if not millions of years," he infers that the modern school of geologists is probably in error in ascribing so much potency to the agents of "subaerial waste," seeing that these have apparently made no impression upon the "bergfall," while the stream itself has only been able to cut a narrow trench in the bottom of the glen since the glacier melted away. But this large bergfall is not of preglacial but of postglacial age. During the last glacial epoch all the glens of that region were filled with ice, the surface of which rose to a height of certainly not less than 3000 feet above what is now the sea-level. After those great glaciers had disappeared, and the streams and rivers were once more permitted to carry on their work, the stream of Glen Beansdale worked its way down through the glaciated rocky floor of the glen, and cumbered this with shingle and boulders. Then the large fall of sandstone took place, and the course of the stream was altered in the manner already described. A new course having been opened out—a process which must have occupied considerable time—wetter and colder conditions of climate ensued, snow-fields accumulated, and a local glacier occupied the glen, following the new course formed by the stream, but never attaining a sufficient size to plough down and clear away the bergfall.

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[1] *Nature*, vol. xx. p. 504.

The local glaciers which existed in postglacial times, that is to say, during the accumulation of the deeper and older deposits of Carse-clay and the formation of the 45-50-feet raised-beach, probably lingered in some valleys till the sea-level had fallen to the 25-30-feet level. But the beaches and Carse-clays of this lower level approximate so closely in character, and in the nature of their organic remains, to the beaches which are now in course of formation, that the temperature of the Scottish seas at the time the waves washed the 25-30-feet level may be supposed not to have differed much, if at all, from that which is experienced at the present day. That the sea stood at that level for a considerable time may be inferred from the amount of work it was able to perform. Broad platforms have been hewn in strata of sandstone and other and often harder rocks which formed the sea-margin; cliffs have been cut back, and considerable caves have been hollowed out at their base by the action of the breakers. Sometimes the old beach consists of only a more or less narrow ledge sawn into the face of a steep rock-slope or cliff, and showing old sea-worn stacks and hollows, at other times it forms a wide flat, two or even more miles in breadth. It is upon these beaches that the greater number of the Scottish seaports and fishing-villages stand. The lower reaches of the great estuarine flats of the Tay, the Forth, the Clyde, the Nith, and others, all belong to the period of the 25-30-feet beach-level, but owing to the working of the rivers it is often difficult in such regions to distinguish between the deposits of the 45-50-feet beach and those of later age. The large rivers in their many windings have ploughed down through the Carse-clays of the older level, and re-arranged these in broad flats and terraces which often merge imperceptibly with the beaches of the 25-30-feet level. This is particularly the case in the Carse of Falkirk, and it may be observed also in the Carse of Gowrie.

The 25-30-feet beach is by far the most persistent and perfect of all the "ancient sea-margins" of Scotland. It is particularly well developed upon the shores of the Firth of Forth, and upon the east coast generally, as at St. Andrews, and between Dundee and Arbroath. Farther north the best-marked raised-beaches occur at lower levels. Upon the south and west coasts, from the Solway as far north at least as the Sound of Jura, the 25-30-feet beach is frequently well displayed, especially upon the shores of Wigton and Ayr shires. The 45-50-feet beach is of much less frequent occurrence. In many cases it is evident that the sea of the 25-30-feet level has demolished the older beach, portions of which are found only here and there fringing the inner margin of the later-formed terrace. Examples of this much-denuded beach occur upon the Wigton coast between Port-Counan and Cairndoon; upon the Ayrshire coast between Girvan and Ayr; upon the shores of Kerrera Sound; in Colonsay and Oronsay; on both coasts of the Firth of Forth, as at Portobello and Kirkcaldy; at Leuchars, Carnoustie, and other places on the east coast. There are also higher beaches (100-feet terrace), which occur here and there in a more or less denuded condition, but these have already been described as pertaining to the closing period of the true Ice Age.[1]

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[1] For notices of "raised-beaches" in Scotland, see *Proc. Geol. Soc.*, vol. ii. pp. 180, 427, 545, 669; *Trans. Geol. Soc.*, 2d Ser., vol. i. p. 416; v. p. 146; *Quart. Journ. Geol. Soc.*, vols. i. p. 217; xi. p. 549; xii. p. 168; xviii. pp. 218, 224; xxi. p. 188; xxii. p. 277; *Edin. New Phil. Journ.*, vol. xxix. p. 94; xxxiv. p. 298; xxxv. p. 278; xli. p. 402; *Ibid.*, 2d Ser., vol. i. pp. 57, 103; *Proc. Berwick Field Club*, vol. i. p. 152; *Proc. Nat. Hist. Soc. Glasgow*, vol. i. p. 127; *Geol. Mag.*, vol. ii. pp. 181, 374; iii. pp. 5, 139, 266, 425; *Proc. Royal Soc. Edin.*, vol. ii. p. 365; *Phil. Mag.*, vol. xi. p. 209; *Brit. Assoc. Rep.*, 1854, p. 78; 1862, p. 73; *Trans. Geol. Soc. Glasg.*, vol. ii. p. 30; *Memoirs Geol. Surv. Scotland; Expl. One-inch Map*, Sheets 1, p. 9; 2, p. 10; 3, p. 24; 4, p. 23; 7, p. 15; 9, p. 44; 13, p. 7; 14, p. 25; 22, p. 30; 31, p. 52; 32, p. 128; 33, p. 67; 34, p. 54. See also R. Chambers's *Ancient Sea Margins*, Maclaren's *Geology of Edinburgh*

So long as our observations are confined to the Postglacial and Recent marine deposits, and the terrestrial and freshwater accumulations which are now and again intercalated with these, we experience generally little difficulty in assigning to each bed, or series of beds, its proper place in the succession. But when we seek to discover the relative age of those lacustrine and peat formations which are scattered over the inland districts, we have little to guide us in coming to any definite conclusion. As a rule, all we can assert is, that they are for the most part of postglacial and recent age. It is quite impossible, however, to refer each particular deposit to its proper place in the series. Yet there can be no doubt that the submarine trees and peat must have their representatives in the interior of the country, although we may be seldom able to pronounce upon these with confidence. This arises from the circumstance that trees representing ancient forests are found buried under peat in positions which clearly prove them to be of later date than the Carse-clays and beach-deposits of the lower level (25-30 feet above the sea), and no inconsiderable portion of the peat with enclosed trees, which occurs in the inland districts, may belong to this later period. The age of forest-growth represented by the submarine trees of the Tay, the Earn, the Forth, and other maritime districts, was followed, as we have seen, by a period of greater humidity, accompanied by a lower temperature. These changed conditions must have told upon the flora throughout the length and breadth of the land. Arboreal vegetation in the neighbourhood of the sea would languish and disappear, and the upward range of oaks and other trees upon the hill-slopes of the interior would become more limited. The increased humidity would, at the same time, give a great impetus to the spread of mosses and marsh-plants, and wide regions formerly covered by trees would eventually become wrapped in a mantle of peat. Hence, we may well believe that many tracts of buried trees and thick peat may

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(1839), p. 228; Fleming's *Lithology of Edinburgh*, p. 85; Hugh Miller's *Sketch-book of Geology*, pp. 14, 60; A. Geikie's *Scenery and Geology of Scotland*, pp. 193, 318.

date back to the period of local glaciers and swollen muddy rivers which carried down to our estuaries the mud and silt of the 45-50-feet level. When the sea had retired to its present limits the climate had again become favourable to the growth of forests, and trees grew over the surface of the Carse-lands, and doubtless re-occupied much of the ground from which they had been compelled to retreat during the ungenial period of local glaciation and extreme humidity. In this manner new generations of trees would occasionally grow over the peaty surface, beneath which the forests of early postglacial times lay buried.

Although peat is commonly dug for fuel in many places in Scotland, yet this is by no means so general as in Ireland, Scandinavia, Denmark, Holland, Northern Germany, and other regions, where coal is less easily and economically obtained. The structure of the Scottish peat-mosses, therefore, is as a rule not so well known as that of the turbaries of other countries. The general phenomena, however, are sufficiently familiar. Peat occurs in Scotland covering here and there wide areas in the Lowlands, and still more extensive regions in the Southern Uplands and the Highlands. It varies in thickness from a foot or two up to ten yards and even more. On hill-tops and hill-slopes it is rarely deeper than from three to six feet, the thickest accumulations occurring upon undulating low grounds and table-lands, and in the bottoms of mountain-valleys. Almost everywhere it covers over the remains of an old forest-vegetation, amongst which the commoner trees are pine, oak, and birch. Besides these, however, we find alder, willow, ash, hazel, and juniper. These trees are often remarkable on account of their great size and their wide distribution. Thus we find roots and trunks of oak in the peat of Banffshire at a height of 3000 feet above the sea, although that tree now finds its northern limits in Ross-shire, Aberdeenshire, and Western Inverness-shire,[1] and does not grow naturally in these northern regions at nearly so extreme an elevation. The large size attained by the bog-oaks has often been remarked upon. Thus in a peat-bog at Benhall, East Kilbride, and again at Thriepwood, Dalserf, both in Lanarkshire, oaks that measured between 60 and 70 feet in length have been obtained at an elevation of 500 feet above the sea. At Thriepwood one of these trees measured 65 feet in length, "and was as straight as the mast of a ship, and so equal in thickness at both ends that it was not easy to say which was the root."[1] This, indeed, is quite a common character of the bog-trees,—they grew close, and tall and straight—showing few or no branches below. The pines are equally remarkable for their size, and had also formerly a wider distribution than at present, and similar remarks apply to the other trees mentioned above. The pine, however, does not appear to have formed any extensive forests at the lowest levels of the country, although its remains have been dug up in many lowland peat-mosses, where oak forms the bulk of the buried timber.

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[1] *Cybele Britannica*, vol. ii. p. 409.

Now and again the peat-bogs contain more than one forest-bed. Thus in the peat of Strathcluony, three successive tiers of Scots firs were observed with peat between. In other places I have been told by peat-diggers that at the bottom of the bogs they usually get oak, and that when an upper stratum or tier of trees occurs the common species is generally Scots fir. I have never been so fortunate, however, as to see such a succession exposed in open section; but from what I have heard, I am led to believe that the phenomenon is by no means uncommon. Very much, however, yet remains to be done by Scottish botanists before our peat-bogs can be said to be as well known as those of the Continent. A systematic examination of the peat-mosses of Lowlands and Highlands would, I feel sure, amply repay any competent observer for his time and labour, for, notwithstanding all that has been written upon the subject, much of that literature is of little value. Very few competent botanists seem to have turned their attention to the matter, and yet from the results obtained by Mr. Axel Blytt in Norway there can be little doubt that similar observations carried on in Scotland would greatly increase our knowledge of the climatic changes which supervened upon the introduction of the Germanic flora.

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[1] Aiton's *Treatise on the Origin, Qualities, and Cultivation of Moss-Earth*, etc., p. xxvii.

Be that, however, as it may, the evidence that we have is yet sufficient to prove, 1st, that Scotland was formerly more extensive, since many peat-bogs in the maritime districts, both of the mainland and the adjoining islands of the Inner and Outer Hebrides, and the Orkneys and Shetlands, contain abundant remains of large trees which could not possibly have grown under present conditions ; 2d, that the climate which induced oaks to grow on the exposed hill-slopes in the north of Scotland at an altitude of 3000 feet, must have been more genial than the present; 3d, that the large pines with their thick bark and resinous wood which occur in certain lowland mosses, seem to point, on the other hand, to a somewhat colder climate. The evidence of the pine would thus appear to clash with that of the oak. But I think this is partly due to the fact that the buried forests really pertain to at least two horizons, and that in many cases the trees obtained from different levels, in one and the same bog, may have been confounded. Nothing indeed, is more likely than that the fact of two successive growths of forest-trees may have passed unnoticed, for sometimes the trees of an upper forest-bed have grown immediately upon the prostrate trunks of a lower series, with only a foot of peat separating the one forest-bed from the other.

I have already described the buried forests of the Tay, the Earn, and the South Esk, and the drifted trees in the Carse-clays of the Forth, and have shown that these grew at a period anterior to the formation of the great estuarine flats. Now upon the surface of those flats an upper forest-bed occurs covered over with peat which reaches a depth in some places of more than a dozen feet. Under the moss of Kincardine (estuary of the Forth) were found innumerable trees and stumps rooted in the subjacent Carse-clay. The trees consisted of oak, birch, alder, willow, mountain-ash, hawthorn, and hazel, and many of them attained a great size. They were found lying in all directions beside their roots, and were buried under peat to a depth of fourteen feet in places. The average thickness of the peat, however, was about seven feet. Here, then, we have clear evidence to show that after the retreat of the sea from the wide Carse-lands of Stirling, a strong forest-vegetation eventually occupied the vacant ground. During the formation of the Carse-clays, the climate, as I have endeavoured to show, must have been cold and ungenial; the Highlands and Southern Uplands had then their permanent snow-fields; local glaciers occupied many of the mountain-valleys; and streams and rivers were frequently torrential in character. While these conditions prevailed it seems most likely that the forests must have disappeared from a large part of the country. The reappearance of great forest-trees, however, rooted in the Carse-clays, shows that the climate afterwards became genial as before. Nor are there wanting indications that seem to show that the land during this second forest-growth extended farther out to sea. At Montrose, as we have seen, the brackish-water Carse-clays, upon the surface of which peat with trees occurs, have evidently at one time stretched farther seawards. They now form low bluffs along the present sea-margin.

The occurrence of at least two successive tiers of trees in certain of the inland peat-mosses seems to me to point to similar climatic changes, and I feel inclined to attribute more importance to the fact of such a succession, than to the prevalence in a given bog of any one particular kind of tree. Were the Scottish peat-mosses as well opened up as those of Norway, I should expect to find the appearance of two or more tiers of trees a common feature in most of our extensive bogs, for it is so in the case of Irish and English peat-mosses. So far as the evidence goes, it leads me to look upon the successive buried forests of some of the inland districts of Scotland as probably synchronous with those old forest-beds which make their appearance below and above the Carse-clays—that is to say, that the submarine forest of the Tay, etc., is contemporaneous with the trees which occur at the base of our deepest inland bogs, while the trees that are dug up at higher levels in the same bogs may belong to approximately the same date as the forest-bed which overlies the Carse-clays. But we may reserve consideration of this point for the present. Its general bearing upon the question of postglacial climate will be pointed out when we come to sum up the evidence later on.

Before leaving the subject of the buried forests of Scotland, I may mention that, while the trees are often found with their heads pointing in all directions, they perhaps more commonly all lie one way—the direction taken corresponding with that of the prevailing wind of the neighbourhood. Marks of fire are said to have been seen upon some of the fallen trees underneath peat, but I have never noticed anything of the kind myself. The stumps and logs are frequently black, decayed, and crumbling, and this appearance, perhaps, has been mistaken for charred wood. Now and again, what are supposed to be marks of adze or hatchet have also been observed upon some of the bog-oaks and other trees; and the Romans have usually been credited with the destruction of the ancient forests. Thus, it has been supposed that the great forest, the remains of which lie buried under Kincardine Moss, was destroyed by the Romans, because: first, the trees looked sometimes as if they had been cut by some sharp instrument; second, "a large round vessel of thin brass and curious workmanship" was discovered upon the surface of the clay, buried under the peat; 3d, some axes and remains of a "corduroy road" were found in the peat, as also a bridge over what had once been a rivulet. None of the metallic remains, however, is Roman in character. The "large round vessel of thin brass," which has been described as a Roman camp-kettle, is a bronze cauldron of precisely the same character as similar objects which have been met with in "finds" belonging to the Bronze Period. The "corduroy road" may or may not be of Roman age, but it did not occur at the bottom of the peat-bog, and evidently belonged to a later date than the great trees of the buried forest. It was "formed of trees about a foot in thickness, having branches half this thickness crossing them, and brushwood covering the whole." At the time this "road" was made Kincardine Moss was "an unstable and boggy waste," as it continued to be down to a recent date, when it was drained.[1] There can be no doubt, however, that the Romans did destroy some portion of the ancient woods. I very much doubt, however, whether Scotland was so well clothed with forest during the Roman occupation as some chroniclers would have us suppose. It seems to me that the known existence of large trees buried under peat has had much to do with the traditions of a well-wooded Scotland in historical times.[2]

Some account has been given above of the terraces of alluvial detritus which are so common a feature in the river valleys of Scotland. Besides these there occur numerous sheets of loam, clay, sand, marl, etc., which mark the sites of ancient lakes, some of which must have been silted up and grown over at a very early period, while others have been drained artificially in recent times. In the lowlands of Scotland they are specially abundant, and many were lakes at so late a date as 1654, for they are shown as such in Bleau's Atlas. The deep drains which have been cut across these alluvial flats frequently show the following succession of beds :—

1. Peat, sometimes containing an upper forest-bed.
2. Ancient forest of oaks and other trees.
3. Loam and marl, with lacustrine shells and remains of red deer, etc.
4. Boulder-clay.

From this succession we may infer, first, that a lake existed for a considerable time so as to allow of the accumulation of the marl, which now and again may reach a thickness of several feet. The marl in many cases would appear to be due to the vital action of *Charæ* and freshwater molluscs, such as *Limnæa* and *Cyclas;* the carbonate of lime being separated by them from the water. The shells themselves have frequently been obliterated by subsequent chemical changes, so that often the marl appears to be quite destitute of any organic structure. Occasionally the marl contains intercalated layers of loam and sand. In other cases, again, we may find little or no marl, the beds underlying the vegetable layers consisting of loam, sand, and gravel. These detrital accumulations were no doubt washed into the lake by rain and rivulets, and they show us how it was gradually silted up. While this process was being carried on trees grew upon the margin of the lake and often dropped their leaves, fruits, and branches into the water. Now and again, too, deer, oxen, and other animals, dying upon the banks of the streams or the lake itself, were floated into the latter, perhaps by sudden freshets, and thus their skeletons eventually became entombed in the mud accumulating below. While the lake diminished in extent, the woodlands of course increased, the trees always occupying the flat reaches as the water retired. And so, by and by, the lake disappeared, and its site was occupied by forest. In some cases, however, a streamlet continued to flow across the dried-up lake-bed, while frequently one or more deep pools or lakelets remained, and have continued to the present day, as in the case of Linton Loch, in Roxburghshire. After the great oaks and their congeners had flourished for a long time, the low-lying ground upon which they grew was converted into a marsh. The trees decayed and fell to the ground, and were gradually enveloped by bog-mosses in their upward growth. Here and there traces of an upper forest-bed sometimes occur in the peat, which would indicate that the marshy conditions ceased, and the area became well fitted for the growth of a second forest. The overlying peat, again, proves that marshy conditions returned, and the second forest succumbed in the same manner as the first.

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[1] Wilson's *Prehistoric Annals of Scotland*, 2d edit., vol. i. p. 52.

[2] See *Trans. Royal Soc. Edin.*, vol. xxiv. p. 368, *et seq.;* and *Great Ice Age*, chap. xxvi.

Remains of the postglacial mammalia have been from time to time obtained in these lacustrine deposits in every part of the country. Among other forms we find *Bos primigenius, B. longi-*

frons, wild-boar, red-deer (often of great size), fallow-deer, roebuck, elk or moose-deer, Irish deer, reindeer, horse, dog, pig, sheep, goat, wild-cat, wolf, fox, and beaver. Some of these animals were extirpated in historic times, and many of them have, of course, been greatly restricted in their range. The beaver was still a native of Scotland so late as the end of the thirteenth century, for its skins are mentioned among Scottish exports in an Act of David I. for fixing the rate of custom duties. But it had apparently become extinct shortly afterwards, for in a similar Act passed in June in 1424, martens, otters, polecats, and foxes are specified, but beavers are never mentioned.[1] On the strength of a passage in the *Orkneyinga Saga*, it is supposed that the reindeer survived in Caithness down to the year 1159. Its remains, however, occur very rarely in Scottish postglacial and recent deposits. Those of the elk (*Cervus alces*) are also somewhat rare, but they have been found more frequently than those of the reindeer. Remains of the Irish deer (*C. megaceros*) are still more uncommon, having been met with only once in deposits of postglacial age. Both the elk and the Irish deer must have disappeared in prehistoric times, and notwithstanding the passage in the *Orkneyinga Saga*, it seems unlikely that the reindeer survived in Scotland to so late a period as the twelfth century.[2] The wolf was still a native of the Highlands in the seventeenth century, the last survivor having been killed in 1680. The great Caledonian bull, which it is supposed by some still survives in the degenerate cattle of Hamilton Park, etc., was probably the direct descendant of the large *Bos primigenius*, and the long-fronted ox (*B. longifrons*) also survives in our domestic breeds. The wild-boar was hunted in historic times, and was killed by that

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[1] Hector Boece (end of fifteenth century) states that in his day the beaver abounded ("incomparabile numero") in Loch Ness, and Bellenden, his translator (probably about 1536), says of the same district that there were "mony wyld hors, and amang yame ar mony martrikis (pine-martins), *bevers*, quhitredis (weasels), and toddis (foxes), the furrings and skynnis of thayme are coft with great price amang uncouth (foreign) merchandis."—*Croniklis of Scotland.* For an interesting account of the Beaver in Britain, see *Trans. Wernerian Soc.*, vol. iii. p. 207.

[2] For accounts of Reindeer, Elk, and Irish Deer in Scotland, see Dr. J. A. Smith in *Proc. Soc. Ant. Scot.*, vol. vii. 1868-69, vol. ix. 1870-71.

"Gordoun, who, for his valour and great manhood, was verie intire with King Malcolme-Kean-Moir." Remains of the red-deer are found in every part of the country, even in many of the outlying islands. It occurs, for example, in the peat of the Orkneys along with human relics.

Nowhere in Scotland have we any relics of Palæolithic man, or any trace of the characteristic Pleistocene mammalia. The oldest postglacial deposits in the country have yielded, in more or less abundance, remains of the well-known postglacial fauna, with bones and relics of Neolithic man, but not a vestige of anything pertaining to the older archæological period has ever been discovered. I have already mentioned the occurrence of a dug-out canoe in the buried forest of the Tay, and have referred to the kitchen-middens of the 45-50-beach of the Forth, and to the numerous canoes and other relics of man which have been dug up in the Carse-clays. In addition to these "finds"—all of which occupy definite geological horizons—similar relics have been met with again and again throughout the country, in river and lacustrine alluvia, and in peat-bogs and caves. Some of these are probably of true Neolithic age, that is to say of older date than the advent in Britain of a bronze-using people. But it is certain that the later Stone Age endured in Scotland far on into the Bronze Period of the Continent. There are kitchen-middens and cave-finds, for example, in which all the human relics appear to consist of stone, bone, and horn, but which can yet be shown on geological grounds to be of later date than the true Bronze Period.

At the time of the 45-50-feet beach of Middle Scotland, Neolithic man lived along the then shores of the Forth,[1] and has left behind him his kitchen-middens, stone implements, bone-harpoons, and canoes to testify to his former presence. When the sea had retired to the 25-30-feet level, however, a knowledge of metals had already been introduced, as we learn from the fact that various objects of bronze and iron have been met with embedded in the estuarine and marine deposits of that stage. Now, in certain districts, upon the upper surface of this later marine terrace and in old sea-caves pertaining to the same level kitchen-middens and other finds occur in which we meet with no trace of metal. This shows us that even after a knowledge of metals had been introduced to Central Scotland, there were people living in northern and other outlying parts of the country who were either entirely ignorant of the use of bronze and iron, or too poor or too far removed from the metalliferous districts to obtain them. At what particular time the sea retreated from the 25-30-feet level has been a much disputed question. But if one may trust to the evidence supplied by local names, the change took place after the land had been occupied by a Celtic-speaking people. Thus, in the Carse of Gowrie, we find prominent mounds, which must have been islands during the formation of the 25-30 feet beach, designated as *Inches*, from the Gaelic "Inis," signifying "island."[1]

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[1] See also for an account of shell-mounds of the same age, discovered at St. Andrews, a paper by Mr. R. Walker, *Philosoph. Mag.*, 1866. Other notices of Scottish kitchen-middens are given by Dr Gordon: *Proc. Roy. Phys. Soc.* Edin., vol. iii. p. 84; W. Laidlay: *Geol. Mag.*, vol. vii. p. 270; J. A. Mahony: *Proc. Nat. Hist. Soc. Glasg.*, vol. ii. (1875), p. 24; R. Gray: *Ibid.*, p. 64. See also for bone-caves of recent age, A. Bryson: *Edin. New Phil. Journ.*, vol. xlix. p. 253; Beattie: *Brit. Ass. Rep.*, 1859, p. 99; *Geol. Mag.*, vol. x. p. 432.

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[1] For an interesting paper on this subject by the Rev. Dr. Milroy, see *Scottish Naturalist*, April and July 1880.

CHAPTER XVIII.

POSTGLACIAL AND RECENT DEPOSITS OF THE BRITISH ISLANDS—*Continued.*

Submerged forests of English coast—Unconformity between Glacial and Postglacial accumulations—Submarine forests of Lancashire and Cheshire—Succession of deposits—General conclusions as to conditions of accumulation—Postglacial and recent deposits of Cornish coast—Section of Happy Union Works, Pentuan—Sections of Lower Pentewan Work—Section at Huel Darlington Mine—General conclusion as to the succession of changes—Sunk forests and buried peat of the Fenland—Relation of Fen-beds to glacial deposits—Character of Fen-beds—General conclusions as to conditions under which they were accumulated.

Submerged forests and peat occur at many places on the coasts of England. They are most frequently met with on low shelving shores where the land falls away with a gentle declivity to the sea. Sometimes they are seen in section in the low cliffs or banks of alluvial and detrital matter which are washed by the water at high-tide; in other places they appear exposed upon the beach at low-tide, and pass outwards for an unknown distance. Borings at various seaport towns also prove the occurrence of similar land-surfaces, at depths of over 40 feet below the present level of the sea. More than this, submerged peat has been dredged off the coasts in 60 feet of water, and it has been detected covering the sea-bottom in the very middle of the English Channel.

The phenomena of submerged forests are not confined to any one part of England, but appear to be characteristic of all the maritime regions, wherever the requisite conditions of a low shelving shore obtain. They are found, for example, upon the coasts of Durham between Sunderland and Hartlepool, upon both sides of the estuary of the Humber; and along the coast of Lincolnshire from Great Grimsby to Skegness. They abound in the low Fenlands that border on the Wash, and are traced here and there upon the shores of East Anglia between the Wash and the Thames, on the banks of which, near and below London, they are well known. Along the shores of the Channel they are plentifully developed. Thus we meet with them in Sussex at Hastings, St. Leonards, Pevensey Level near Eastbourne, and Bracklesham; and they are equally abundant upon the coasts of Devon and Cornwall, as at Torre Abbey near Torquay, at Blackpool, and on the shores of Salcombe estuary, of Bigbury Bay, and of Millendreth Bay near the Looes. Farther west they occur at Mainporth, between Falmouth and Mawnan, at Porthleven near Helston, and on the margin of Mount's Bay. Upon the west coasts of Cornwall and Devon they are not less commonly met with, as at Hayle, Perran Porth, Barnstaple, and Bideford Bay. They occur also on both sides of the Bristol Channel, as at Porlock, Watchet, and Sharpness, and the shores of Caermarthen Bay at Tenby. Upon the west coast of Wales they are found in St. Bride's Bay, at Mount and Aberaeron in Cardigan, and at Holyhead. Again, we meet with them in Denbighshire, as at Llandrillo Bay, and they are particularly well developed between the mouths of the Dee and the Mersey, and especially upon the shores of the latter estuary. Farther north, they appear upon the low shores of Morecambe Bay, and they are also known upon the borders of the Solway Firth.

There can be no question that all these sunk forests represent former land-surfaces. Abundantly exposed as they are, we have yet very good reason for believing that they are even more continuous than they appear to be. Some of them are only visible at rare intervals, when after some great storm the sea has suddenly swept away the modern beach-deposits under which they ordinarily lie buried. Others, again, as we learn from borings, are permanently covered, and but for those borings would never have been known to exist. There can be but little doubt, therefore, that many old land-surfaces must lie concealed below recent beach and estuarine accumulations upon most of the low shelving shores of England.

In the majority of cases the trees are found rooted in the old soil. They consist of the common species which are still indigenous to Britain, such as oak, pine, hazel, birch, alder, ash, yew, etc. The vegetable layer varies from less than one foot up to twelve feet or even twenty feet in thickness, and appears in some cases to be entirely composed of the *débris* of trees. More commonly, however, the remains of trees occur at the base of the bed, and are covered over with peat formed of sphagnum, sedges, rushes, or other marsh-loving plants. As might have been expected from their extensive distribution, the submerged forests repose upon strata of widely different ages. In certain districts, for example, the immediately-underlying stratum may be some member of the glacial series, while in other places the trees are rooted in Palæolithic and ossiferous gravels, or in strata belonging to the older Tertiary formations. But in no single instance do they rest upon any passage-beds which might serve to bridge over the hiatus which obtains between the close of the Glacial Period and the beginning of Postglacial times. There is everywhere an unconformity between the peat-beds and the latest of the glacial deposits upon which they may chance to repose. The Ice Age had passed away and the later glacial deposits had been greatly eroded long before the trees of the submarine forests had begun to grow. To make this clear a few typical cases will be described.

Among the most noteworthy of the submarine forests of England are those which extend along the maritime districts of Cheshire and Lancashire from the mouth of the Dee to Morecambe Bay. The old forest-beds of the Mersey and the neighbouring coasts have been long known and frequently described by antiquarians and others, from Leland's time down to the present day, so that we are pretty well informed as to their character and the mode of their occurrence. A most interesting résumé of all that antiquarians have been able to tell us about them is given by Dr. Hume,[1] and, as his account is also to some extent geological, it may be consulted with advantage by those who are desirous of studying the matter in detail. A more critical description of the deposits from a geological point of view is furnished by Mr. C. de Rance,[2] who examined the districts in question for the Geological Survey, and Mr. Mellard Reade[3] and others have also done much to increase our knowledge of the Postglacial history of West Lancashire and Cheshire.

The area occupied by the Postglacial and Recent deposits extends, as I have said, along the maritime regions of Cheshire and Lancashire, and forms a low-lying plain that stretches inland for several miles from the shore. Its inner margin is pretty well defined by the 25-feet contour-line, but a large part of its surface is below the level of the sea, which is kept out by a long range of sand-hills that fringe the coast-line, and here and there by artificial embankments. The deposits met with throughout this broad belt of low ground vary considerably in thickness, and seem upon the whole to reach their greatest depth in the immediate vicinity of the coast-line, and what appear to be old buried valleys. As they pass inland they generally become thinner. Sometimes they do not exceed six, ten, or a dozen feet in thickness, while in other places they swell out to 80 feet. As might have been expected, the various beds of the series seldom maintain a definite thickness for any distance, but swell out and thin off irregularly, so that the sections exposed in one district often differ considerably from those that are seen in other places. And the numerous borings which have been made for various purposes tell the same tale. The general succession, however, according to Mr. de Rance, is as follows :—[1]

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[1] "Examination of the Changes in the Sea-coast of Lancashire and Cheshire." *Supplement to Ancient Meols.*

[2] *Quart. Journ. Geol. Soc.*, vol. xxvi. p. 657; *Proc. Geol. Assoc.*, vol. iv. No. 4.

[3] *Geological Magazine*, vol. ix. p. 111; *Proc. Geol. Soc. Liverpool* (1872), vols. xiii. p. 36; xiv. p. 42. The reader will find in these and the works mentioned in the preceding notes, references to papers by Mr. H. Ecroyd Smith, who has paid special attention to the antiquarian aspect of the question, and by Mr. J. P. G. Smith, Mr. Cunningham, and others, who have published interesting notices and sections showing the succession of the deposits.

1. Sand dunes.
2. Upper clay and silt, partly marine (*Scrobicularia piperata*) and partly freshwater (*Cyclas cornea*).
3. Upper peat and forest-bed.
4. Lower clay and silt, partly marine (*Scrobicularia piperata*) and partly freshwater (*Cyclas cornea*).
5. Sand, with comminuted fragments of *Cardium edule* and *Turritella communis.*
6. Lower peat and forest-bed.

The bottom upon which the deposits rest is almost invariably boulder-clay, but now and then they repose directly upon the sandstones of the Triassic formation. From this succession one might draw several conclusions bearing upon the general geographical and climatic conditions of Britain, but for the present we shall confine ourselves as closely as may be to the purely local aspect of the evidence. First, then, we must observe that here, as in Scotland, there is a strongly-marked unconformity between the postglacial beds and the boulder-clay that forms their pavement. Long before the trees of the lower peat began to grow the ice-sheet had melted away, and its bottom-moraine had been deeply incised by streams and rivers. No trace of late glacial shell-beds has been met with underneath the peat—these, if they ever existed, have entirely disappeared. We pass at once from the relics of an intensely arctic condition of things to the remains of an abundant forest-vegetation. This unconformity, therefore, indicates a gap in the evidence. A very long time must have elapsed between the final melting of the last great ice-sheet and the advent of the Germanic flora.

The lower peat varies in thickness from 2 inches to 10 feet.

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[1] As the short account I give of these interesting deposits is merely meant for comparison with the succession met with in other regions, I have not thought it necessary to employ the local names used by Mr. de Rance, Mr. Mellard Reade, and others.

The trees which it contains are in many cases rooted in the underlying boulder-clay, so that there can be no doubt that they actually grew *in situ.* They consist of the usual species—oak, pine, hazel, etc. Some of the flint weapons in the Liverpool Museum are believed to have been derived from this peat-bed, and it is said by Mr. Ecroyd Smith to have yielded bones of the urus and great Irish deer, but Mr. de Rance doubts whether this is the case, and is of opinion that neither animal remains nor any trace of man or his works have yet been discovered in this oldest member of the postglacial series.

The sand (No. 5) occurs chiefly in the form of sand-hills along the eastern or inner margin of the great plains, but is continued underneath the overlying deposits to the west. It is believed by Mr. de Rance to have been formed by the action of the sea and wind at a time when the land stood at a relatively lower elevation than the present, and the coast corresponded pretty closely with what is now the 25-feet contour-line. The sand was then spread out partly in shallow water and partly upon the beach, and was blown inland so as to form a series of dunes corresponding in character to the sand-hills which fringe the modern coast. They tell us, then, of a time when the land, which, during the growth of the lower buried forest, must have extended much farther out to sea than it now does, gradually became submerged to a depth below its present level of some 25 feet or thereabout. Before this submergence was fully accomplished the trees had succumbed to the influence of increasing moisture—marshes gradually extended their bounds, and wide stretches of peat ere long occupied the site of the ancient forest. By and by the sea itself invaded the broad flats, here sweeping away the peat and prostrate timber, and there covering it up with sand and silt and clay (No. 4). At the same time the submerged portions of the river-valleys were filled up and levelled with the floor of the sea. After these conditions had obtained for some time the shallowing sea was here and there excluded from the mud-flats, and wide lakes of fresh water were formed. In these lakes gray silts were accumulated, and *Cyclas cornea* abounded. As the mud-flats continued to be deserted by the sea, trees again began to appear —the vegetation gradually becoming more abundant, until at length a dense forest-growth prevailed. The trees, which consisted largely of oak and Scots fir, often attained great dimensions, and there are some indications which lead to the belief that among the first to occupy the vacant ground was the Scots fir. But however this may be, the whole of the lowlands eventually became thickly wooded with a varied vegetation—amongst which, besides oak and Scots fir, were ash, beech (?), alder, and yew. Eventually, however, another change ensued ; the trees decayed, and the wide wooded plains became converted into marshes. Peat now began to spread abundantly, and by and by covered over the site of the old woodlands. The surface of the peat seems to have been varied here and there with shrubby growths of holly, hazel, and spurge, which flourished then in the drier places, very much in the same way as willow and spurge are growing in the district now. At the time the great forests were flourishing the sea must have been at a greater distance—in other words, the land must have extended westwards considerably farther than at present into the Irish Sea. The decay and overthrow of the trees and the growth of peat appear to have been accompanied by a considerable loss of land. The sea gained upon the coast, and here and there an upper marine clay came to be laid down upon the surface of the peat.

Mr. de Rance observes that the oldest relics of man, which consist of implements of Neolithic age, occur in the lower clay and silt (No. 4). The same bed, according to Mr. Ecroyd Smith, has yielded remains of the urus (*Bos primigenius*), the great Irish deer (*Cervus megaceros*), and cetaceans. From the upper peat and forest-bed have come Celtic and Roman relics, the former of which belong to the lower and the latter to the upper portion of the bed.

Briefly summing up the evidence, we seem justified in coming to the following conclusions :—

1st, That the lower forest-bed points to a former wider extent of land and a climate capable of nourishing and sustaining an abundant forest-vegetation.

2d, That the peat, underneath which these trees lie buried, indicates more humid conditions, which brought about the decay and overthrow of the forests, and fostered an abundant growth of marsh-plants.

3d, That the wide peat-covered plains eventually sank under the sea to a depth below its present level of 25 feet or thereabout. Neolithic man was at this time an occupant of the land.

4th, That by and by the sea again slowly retreated, and wide freshwater lakes made their appearance.

5th, That the upper forest-bed points to a recurrence of genial climatic conditions probably similar to those underneath which the trees of the lower forest-bed flourished; and that the land at this time was more extensive than it is now.

6th, That the upper peat implies more humid conditions, adverse to the growth of great forests but favourable to that of marsh-plants.

7th, That the beds above the peat indicate a recent encroachment of the sea—an encroachment which had probably commenced before the destruction of the forests was completed.

We may now take a glance at the Postglacial and Recent deposits of the Cornish coast. The only accumulations in Cornwall which can be recognised as pertaining to the Ice Age are certain raised-beaches and the peculiar earthy and stony *débris* ("head") which caps them. These, as we have seen, belong probably to the last interglacial epoch and the final cold stage of the Glacial Period, and we have next to inquire what were the physical and climatic conditions that obtained in Cornwall subsequent to the accumulation of the well-known "head," and the formation of the coarse gravels and stones of the famous stream-tin deposits. The nature of these deposits is revealed to us by the numerous sections which have been made in the search for tin, and there is certainly a marked similarity in the general succession of the beds. At the bottom occurs the "tin-ground," a somewhat tumultuous or torrential accumulation of angular and sub-angular stones and rocks mixed with sand and gravel. The blocks, as already mentioned, vary in size from a foot or less up to masses several feet, or even yards, in diameter. The general character of the deposits above the tin-ground will be best gathered from the sections which follow.

Section of Happy Union Works, Pentuan (1829).[1]

1.	Rough river-sand and gravel, here and there mixed with sea-sand and silt. A row of wooden piles with their tops 24 feet from the surface, apparently intended for a bridge, was found on a level with spring-tide low-water	20 ft.
2.	Sand ; trees all through it, chiefly oaks, lying in all directions ; animal remains, bones of red deer, hog, human skulls (?), bones of whale . .	20 ft.
3.	Silt or clay and layers of stones, a conglomerate of sand, silt, bones, and wood	2 ft.
4.	Sand with marine shells ; water draining through this bed is salt above, fresh below . . .	4 in.
5.	Sludge or silt, brownish to a lead colour in places, with recent shells which, particularly the bivalves, are often in layers, double and closed, with the siphonal end upward, rendering it likely that they lived and died there. They are of the same species as those existing in the neighbouring sea. Wood, hazel-nuts, and occasionally bones and horns of deer and oxen, are found in this bed ; a piece of oak shaped as if by man, with a barnacle attached, was found at 2 feet from the top .	10 ft.
6.	A layer of leaves, hazel-nuts, sticks, and moss (in a perfect state, almost retaining its natural colour, apparently where it grew). It extends, with some interruptions, across the valley, occurs at 30 feet below low-water mark, and about 48 feet below spring-tide high-water	6 in. to 12 in.
7.	Dark silt, apparently mixed with decomposed vegetable matter	1 ft.

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[1] De La Beche, *Report on the Geology of Cornwall, Devon, and West Somerset*, p. 401. The section is given in descending order.

8. Roots of trees in their natural position ; oaks with fibres traceable for 2 feet deep. From the manner in which they spread there can be no doubt but that the trees have grown and fallen on the spots where their roots are found. Oysters still remain fastened to some of the larger stones and to the stumps of trees.
9. Tin-ground, with rounded pieces of granite, and subangular pieces of slate and greenstone. Most of the tin occurs in the lower part, from the size of the finest sand to pebbles 10 lbs. in weight ; some rocks highly impregnated with tin weigh 200 lbs. and upwards. Thickness (including No. 8) from 3 ft. to 10 ft.

This section occurs near the sea ; when the tin-ground is followed inland, the marine deposits disappear and the stanniferous gravel is covered directly by freshwater accumulations. It must not be supposed that all the tin-workings in the neighbourhood of the sea exhibit precisely the same succession of deposits as that given in the above section, but they agree generally in showing that the tin-ground is overlaid directly by an old forest-bed, and that this bed is in turn buried under marine, estuarine, and fluviatile deposits. Resting upon these overlying deposits, and sometimes intercalated with them, occur occasional seams of vegetable matter, and now and again a well-defined bed of peat with roots of trees occurs near the top of the series, as in the following section :—

Section of Lower Pentewan Work, $\frac{1}{4}$ mile from sea-beach. [1]

	Feet.
1. Soil with growing trees, some very old ; gravelly towards the bottom	3
2. Fine peat, roots of trees, fallen trunks, sticks, ivy, sea laver, rushes, impregnated with salt	12
3. Sea-mud, with compressed leaves at the top, cockles at 31 feet from the surface, bones, human skulls (one of a child), deer horns. At the bottom a bed of very small shells, a foot in thickness	20
4. Sea-mud, oysters and cockles	4
5. Compressed leaves, vegetable matter, a few rotten shells .	$6\frac{1}{2}$

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[1] *Trans. Royal Geol. Soc. Cornwall*, vol. iv. p. 404.

	Feet.
6. Vegetable matter, rushes, fallen trees, leaves, roots, moss, the elytra of coleopterous insects	1
7. Moss, hazel-nuts, sticks, on pebbles of killas, growan, etc.	3
8. Rough tin-ground	5

Another section given by Mr. Smith is as follows :—

SECTION OF PENTEWAN WORK.

Sandy clay, stones, gravel	9
Peat, with roots and leaves	7
Sand, with branches and trunks of trees	8
Finer sand, with shells, bones, horns, vertebra of a whale, human skulls	12
Coarse gravel	2
Close sand with clay, becoming peaty near the base	12
Loose stones and gravel, 1 foot thick resting on tin-ground.	

Besides the buried forests which are revealed to us by the tin-workings, geologists have long been familiar with the fact that the Cornish coast exhibits in many places the phenomena of submarine peat and trees. These, there can be little doubt, are merely prolongations seaward of the peat and buried trees that are cut through by the stream-tin works. But whether the submerged forests of the sea-coast always pertain to the same level as the vegetable layer which is usually found resting directly upon the stream-tin gravels may be questioned. Mr. Carne, however, thought he could correlate the bottom forest-bed (No. 4) in the following section with the famous submerged forest of Mount's Bay :—

SECTION AT HUEL DARLINGTON MINE, MARAZION MARSH.[1]

1. Gravel and loose ground	8 ft.
2. Peat, with minute woody fibre	4 ft.
3. White sand, with *Cardium edule*	12 ft.
4. Oak and hazel trees lying in all directions ; hazel-nuts loose and on their branches ; a piece of oak, shaped as if for a boat-keel	1 ft. to 2 ft.
5. Solid hard peat, closer than the upper bed	3 ft.
6. Alluvial tin-ground on slate-rock	4 ft.

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[1] *Trans. Royal. Geol. Soc. Cornwall,* vol. vi.

Mr. W. A. E. Ussher also, in his admirable and exhaustive summary of the evidence,[1] seems inclined to connect the submerged forests generally with the stratum of vegetable matter, or of detritus mixed with vegetable matter, which rests directly on the tin-gravels. Mr. Ussher speaks with a full knowledge of the subject, and I do not willingly call in question the reasonableness of his conclusion ; but, after subjecting all the published evidence to careful scrutiny, I have been unable to discover the grounds upon which it is assumed that the lower peat and trees which rest upon the tin-gravels are necessarily synchronous with the submerged forests exposed upon the present foreshore. In some cases this may be the fact, but it is hard to believe, on the evidence produced, that this correlation can be generally sustained. Take, for example, the section of Happy Union Works, Pentuan. In this section I should suppose that the trees and other remains in bed No. 2 rather than those in bed No. 8 were contemporaneous with the submerged peat and trees which are so often exposed upon the shore at low-water. The latter do not rest directly upon stanniferous gravels. In nearly every case where the nature of the stratum below the forest-bed of the foreshore has been observed this is stated to be clay, and in the reclaimed marsh-land between Marazion and Ludgvan, where the peat sometimes attains a thickness of 4 to 7 feet, it is said to rest on a bed containing *Cardium edule.* In the case of the submerged forest of Mount's Bay the pavement is either clay-slate or bluish sand, and in one place a mass of gravel. It seems to me, therefore, most probable that all the submerged forests and peat which are seen exposed between low and high water, or which occur at or near the present sea-level, rest either upon the older rocks of the district or upon those fluviatile, estuarine, and marine beds or their equivalents, underneath which the tin-gravels lie buried, sometimes at a depth of 60 or 70 feet ; and that the ancient buried forest and peat, which repose directly upon those gravels, are the relic of a much older land-surface than that which is represented by the submarine forests of the present coast-line.

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[1] *Geological Magazine,* Dec. ii. vol. vi. p. 251 ; *The Post-Tertiary Geology of Cornwall,* p. 45.

The flora of the lower buried forest differs in no essential particular apparently from that of the submarine forests and layers of vegetable matter which occur above the marine and estuarine beds ; and it is interesting to observe that human relics and remains are found associated with both series. The mammalian remains belong to those cervine and bovine animals which usually accompany the postglacial and recent peat of our islands. Among the species are the Irish deer, the roebuck, and the urus. It is not necessary for my purpose to go into more detail. Those who wish to be fully informed upon the subject will do well to consult the papers of Mr. Godwin-Austen in the Geological Society's Journal, and the very full and informative essays by Mr. Ussher, in which the reader will find a complete digest of all the facts known in connection with the Post-Tertiary and Recent deposits of Cornwall.

From the evidence, of which I have given only a meagre outline, the following inferences seem to me to be fully justified :—

1st, The tin-gravels, of which I have spoken in a former chapter, we may consider as representative of the closing part of the Glacial Period. They speak to a time when the climate was more humid and probably colder than the present, and when the streams had quite a torrential character ; and as the deposits in question pass below the level of the sea they necessarily indicate a former greater elevation of the land. This, however, need not have been excessive. An elevation of less than 100 feet would bring all the known stream-tin gravels above the reach of high-water, and we have no evidence to show that the land during their accumulation was any higher.

2d, Before the growth of the lower buried forest began the formation of tumultuous river-gravels and *débris* had ceased. The streams, whatever they may have been doing in their upper reaches, were now no longer able to carry down to low levels the great boulders and coarse gravel which pave their ancient beds.

The climate had undergone a great change, and the land became covered with a strong forest-growth. At the time those trees flourished the coast must necessarily have extended much farther out to sea, since the old land-surface occurs in places at a depth of not less than 67 feet below the present sea-level. Man and the postglacial mammalia were then in full occupation of the ground. No trace of any of the extinct or migrated pachyderms which were characteristic of Palæolithic times has ever been found at this horizon, nor has any relic of Palæolithic man himself been encountered. Here, as in Scotland and the north-west of England, we find the postglacial deposits resting directly upon accumulations belonging to the Glacial Period. There are no passage-beds bridging over the gulf that separates the disappearance of cold conditions from the advent of that genial climate which nourished the great forest-growths of early postglacial times. Possibly, however, were the lower portions of the buried forest sufficiently examined, such evidence as we are in want of might be forthcoming. It is not unlikely that some lucky botanist may yet be able to detect there certain traces of a flora indicative of colder conditions than obtained when the oak and its congeners first entered Cornwall.

3d, The beds overlying the old buried forest prove that after a prolonged time the sea gained upon the land to some extent, and the ancient forests that occupied the low grounds were submerged. At this stage the land would appear to have stood at very much the same level as at present. Doubtless the loss of land would tell upon the climate of the maritime districts, and we may well believe that the great trees had succumbed before the sea actually overwhelmed them. Mr. Ussher remarks that "the peaty matter so constantly associated with the forest-bed, though it might in some cases be explained by the saturation of an old vegetable soil forming round the trees for centuries, would as a rule impress one with the idea that the forest-tracts were converted into marshes by the formation of gravel- or sand-bars damming back the drainage of the valleys for some time before the sea regained its old cliff-bounds." But as the occurrence of peat overlying ancient forests is not an isolated phenomenon peculiar to maritime districts, but common to all turbaries throughout the British Islands and Northern Europe, it seems more natural to attribute the presence of the peat in most cases to changed climatic conditions, which, while unfavourable to the growth of arboreal vegetation, greatly nourished the spread of mosses and marsh-plants. To this subject, however, I shall return. The presence of human relics in the marine beds shows that man still lived in Cornwall after the low grounds were submerged.

4th, During the period of submergence streams continued to carry sand and silt down to the sea, and now and again quantities of vegetable matter were likewise distributed over the beds of the estuaries. Some of this vegetable *débris* may have been derived from the destruction of the old forest-lands which covered the upper reaches of the valleys and the inland districts generally. It seems in every way comparable with the layers of drifted vegetable matter which occur in the Carse-deposits of the Forth. We may suppose that owing to an increased rainfall the streams frequently rose in flood, and, overflowing the low grounds within their reach, swept them bare of their vegetable covering. It is by no means necessary, however, to infer that the sticks, boughs, twigs, etc., which occur locally here and there in the estuarine beds, are in every case the *débris* of trees which were growing in the vicinity of the Cornish coast-line during the period of submergence. The encroachment of the sea, apart from any other cause, must have told upon the flora; and we can hardly escape from the conclusion that long before the lower forest-bed had been completely overwhelmed the growth of arboreal vegetation must have received a severe check over a wide district in Cornwall. The old forests must in many cases have decayed and given rise to marshes, so that when the streams rose in flood nothing is more likely than that these should sweep seawards such relics of the ancient woods as came within their reach. In this manner whole rafts of matted vegetation might now and again be undermined and floated off *en masse*. As this would happen from time to time, we need feel no surprise at meeting with layers of peat and woody matter at various levels in the estuarine and fluviatile deposits that overlie the ancient forest-bed. It is also quite possible that some of those peat-beds may really represent old land-surfaces or marshes, formed, as Mr. Ussher remarks, "at different times and in different places from alterations in river-courses or stoppages of drainage."

5th, After a time another change took place in the relative level of sea and land. The sea gradually retreated and left the estuarine and marine deposits exposed. This alteration of level seems to have been accompanied also by the return of conditions favourable to the growth of large trees. The land must then have stretched southward for a considerable distance. This inference is necessitated by the presence of the oaks, elms, and other trees of the so-called submarine forests of the present fore-shores, and the upper bed of peat with tree-roots which is found in certain stream-tin sections resting upon the surface of the fluviatile and estuarine deposits. It is hardly possible that so strong a forest-growth could have taken place in the immediate vicinity of the sea.

6th, The position now occupied by the submarine trees points to a recent submergence, the proximity of the sea bringing about conditions adverse to the growth of trees, and producing the present general bare appearance of the Cornish coast-lands.

I shall now ask my reader to take a brief glance at the evidence supplied by the sunk forests and buried peat of the Fenland. These have been described by many writers, and the general facts have long been known, but it would seem from the recent exhaustive exploration of the district by Mr. S. B. J. Skertchly of the Geological Survey that some of the views which have hitherto prevailed are not quite correct. The region of the Fenland, as every one knows, extends inland to west and south from the borders of the Wash, so as to embrace an area of more than 1000 square miles, the widest tract of level ground in Britain. This great stretch of flat land consists of superficial accumulations of silt and peat with underlying gravel, which occupy a shallow basin scooped out of older deposits. According to Mr. Skertchly the oldest of the true Fen-beds are certain unfossiliferous gravels, which are found almost everywhere paving the bottom of the ancient silted-up basin, and extending more or less continuously along the margin of the Fenland, where, according to the same writer, they evidently indicate a former line of beach. The beds above these beach- and floor-gravels consist of silt, peat, and shell-marl, which interosculate in such a manner as to show that they are frequently of contemporaneous origin, that is to say, that the peat and shell-marl in one place have been formed at the same time that silt was accumulating elsewhere. Thus it is very difficult or impossible to correlate the beds in one district with those which occur in other places. All that can be said is that the formation of peat and silt has progressed contemporaneously and alternately throughout a long period of time, and some idea of the lapse of time required for the accumulation of the Fen-beds may be gathered from examining a few sections taken at different places. But before doing so it is necessary to inquire into the relation which the true Fen-beds bear to the glacial deposits of that region. The basin in which the former lie has been excavated partly in Oolitic strata and partly in boulder-clay. This boulder-clay is the *boue glaciaire* of the great ice-sheet which, as I have already stated, there are good grounds for believing, flowed south as far as the valley of the Thames. It belongs to the climax of the Glacial Period, and is therefore of vastly greater antiquity than any portion of the Fen-beds, however ancient these may be. Here and there the level surface of the Fenland is broken by the presence of slight hills and rising grounds, which form islands, as it were, in the wide expanse. These islands are composed of ancient river- and estuarine-gravels resting upon boulder-clay; and they indicate, as Mr. Skertchly remarks, the former existence of a land higher than the present, when the coast-line was not so far east. The gravels have yielded Palæolithic implements and remains of the mammalia characteristic of Pleistocene times. It is quite clear, then, that a great interval separates the formation of the Fen-beds from the deposition of the Palæolithic gravels. The old land occupied by Palæolithic man and his congeners had been worn down by river-action, and cut back for miles by the sea before the oldest of the Fen-beds began to accumulate. There is, in short, an abrupt break between the Palæolithic deposits and the overlying more recent accumulations, the latter rest upon a highly denuded surface of the former.

The lowest of the Fen-beds consists, as I have said, of gravel. Unfortunately this gravel appears to contain no marine fossils, the only marine organism detected by Mr. Skertchly being a patch of *Flustra* on a pebble, which of itself would not be enough to prove that the gravel originated in the sea. He mentions, moreover, that some mammalian remains referable to cervine and bovine animals (*Bos primigenius* and *B. longifrons*) have been met with. The occurrence of these does not of course militate against the marine origin of the beds, for the remains in question may have been carried down by streams or washed away from the shore by the tide, and thrown up again by the waves. But, so far as I can learn, the marine nature of the gravels is based chiefly upon the mode of their occurrence. According to Mr. Skertchly they stretch along the margin of the Fenland in a pretty continuous band from Sleaford to Peterborough, at both which points they merge into "valley-gravels," that is to say, gravels of fluviatile origin. They clearly pass under the silt and peat, and as similar gravels are encountered again and again in cuttings, borings, and other sections throughout the Fenland, it is inferred that "they form a more or less complete flooring to the basin, just as at the present time the bottom of the Wash is similarly covered." Their intimate connection with the silt and peat that overlie them "is shown by the occurrence here and there of patches of those materials in the gravel itself." If we take this fact in connection with the presence of the mammalian remains mentioned above, we arrive at the conclusion that whatever may be the origin of the "beach-" and "floor-gravels" of the Fenland, they cannot belong to the glacial series. Both by their geological position and their organic contents they are proved to be of postglacial age.

The beds above the gravels are composed of peat, shell-marl, and marine silt and clay, with *Scrobicularia piperata*. The gravel-paved basin in which these accumulations rest has been gradually conquered from the sea chiefly by the deposition of silt brought in, says Mr. Skertchly, by the sea itself, and laid down only at the slack of high-water upon the coast; and this process has been going on apparently with little interruption since the Fen peat and silt began to form. We have evidence, however, in the presence of buried forests at some depths below the present sea-level that the land was formerly more extensive than it is now. Mr. Skertchly gives a table showing the depths from the surface at which buried forests have been found. They occur, he says, on at least four horizons, and in one place he observed no fewer than five buried forests one above another, with separating beds of peat. The lowest forest rests upon the floor-gravels, which form the basement beds of the Fen-series, and its presence clearly indicates that, after the deposition of the gravels, the sea retreated, and a well-drained land-surface existed in its stead. "The next horizon includes the trees which occur at about 10 feet from the surface; the third those about 5 feet from the surface; the fourth those nearer the surface than the third." It must not be supposed that those various buried forests occur constantly throughout the Fenland. On the contrary, some sections may show only three or two, or even again only one. The most constant of all the forests appears to be the lowest—that namely which rests upon the basement gravel-beds. The trees and shrubs comprise oak (*Quercus robur*), pine (probably *Pinus sylvestris*), elm, yew, birch, hazel, alder, and willow (several species), all of which, with the exception of *Pinus sylvestris*, are still natives of the Fenland.

Each forest-bed is generally covered by a less or greater thickness of peat, but it must be understood that the peat of the Fens is not necessarily always associated with buried trees. In many places thick and extensive beds of this material occur in which no trace of trees has been found. Not only so, but similar seams of peat are observed interstratified again and again with marine silt and clay.

Shell-marl is also a deposit which occupies considerable areas in the Fenland, and points to the former existence of wide shallow lakes or meres. It abounds with the shells of such genera as *Pisidium, Planorbis, Limnæa, Cyclas, Succinea,* etc.

Human relics and remains have been met with at various depths in the Fen-deposits. These comprise, besides stone implements of Neolithic forms, "dug-out" canoes. One of these is said to have been of oak, and the tree out of which it was fashioned was estimated to have contained 650 cubic feet of timber. Remains of the usual postglacial fauna are common enough in some places, among them being *Bos primigenius, B. longifrons,* fox, wolf, beaver, roebuck, red-deer, great Irish deer, reindeer, otter, marten, wild-boar, and brown bear. In the marine deposits occur the common seal, the Greenland whale, the walrus, etc. But in none of the true Fen-beds has any trace been discovered of the extinct forms characteristic of Palæolithic times.

From the facts now briefly summarised the following inferences may be reasonably deduced :—

1st, The beach- and floor-gravels probably indicate an early postglacial submergence ; but in the absence of marine remains this cannot perhaps be asserted with perfect confidence. These earliest deposits clearly prove by their position that a great lapse of time supervened between the accumulation of the Palæolithic gravels of East Anglia, and the formation of the true Fen-beds. The Palæolithic and the Neolithic series are not conformable ; the latter rest upon the worn and wasted surface of the former.

2d, At the base of the Fen-peat and silt there appears an old buried forest, the position of which (30 feet below the present sea-level) speaks to a former wider extent of land. The climate was then favourable to the growth of trees ; by and by, however, these conditions were changed—the forest decayed and was grown over by peat, chiefly composed of the moss *Hypnum fluitans.*

3d, The succeeding deposits of marine silt with *Scrobicularia piperata* indicate a limited submergence of the land.

4th, The sea again retreated to a lower level than at present, and a second forest-growth covered the area of the Fenland. To this date also probably belong the submarine forests which occur upon the sea-coast at Holme and Hunstanton in Brancaster Bay, and at Skegness and northwards on the Lincolnshire coast. After this second forest had flourished for a time, it eventually succumbed to adverse conditions, and was overwhelmed by the growth of peat.

5th, Submergence of the land accompanied and followed this change.

6th, The marine silt, peat, and sporadic layers of trees, which occur in the Fenland at higher levels than the second forest-bed, point to the gradual silting-up of the Wash, and the alternate prevalence of humid and dry conditions on the reclaimed areas.

CHAPTER XIX.

POSTGLACIAL AND RECENT DEPOSITS OF THE BRITISH ISLANDS—*Continued.*

Correlation of English Postglacial accumulations—Résumé of the evidence—Raised-beaches of English coasts—Postglacial accumulations of inland districts—Their unconformability to Glacial and Palæolithic deposits—English rivers of larger volume in Postglacial times—Lacustrine alluvia and peat-bogs of England—Their organic remains—Succession of forest-layers in English peat—Arctic flora at Bovey Tracey—Postglacial mammals of England—Postglacial and Recent deposits of Ireland—Submarine trees and peat—Raised-beaches—Neolithic kitchen-middens—Successive tiers of trees in bogs of inland districts—Mr. Kinahan's observations on succession of changes which these imply—Human relics in Irish bogs—Postglacial mammalia.

THE English Postglacial beds, of which I have now given a short sketch, while they certainly differ in detail in the separate regions where they occur, yet possess certain characters in common which allow us to compare and correlate them. If, after examining the evidence, we shall discover that certain strongly-marked features present themselves in each of the typical districts which have been passed under review, we shall naturally attach greater importance to these than to such features as appear to be more or less local in their occurrence. Beginning then with the Postglacial and Recent deposits of the north-west coasts, we find that these may be grouped as follows :—

1. *Lower Buried Forest :* greater extent of land than now, climate genial.
2. *Lower Peat :* conditions unfavourable to forest growth ; climate probably more humid than that of No. 1.

3. *Marine deposits:* submergence of land to a depth of 25 feet or thereabout below its present level.
4. *Lacustrine deposits,* and *Upper Buried Forest:* re-emergence of land; wide shallow lakes; great forest-growth; climate genial.
5. *Upper Peat,* and *Lacustrine deposits:* conditions unfavourable to forest-growth; climate probably like that of No. 2.
6. *Marine deposits* of present coast: recent advance of the sea.

Now, compare with this the succession met with in Cornwall, which may be taken as follows:—

1. *Lower Buried Forest:* greater extent of land than now; climate genial.
2. *Lower Peat:* conditions unfavourable to forest-growth; climate probably more humid than that of No. 1.
3. *Marine* and *Estuarine deposits:* submergence of land to a depth of 50 or 60 feet or so below its present level.
4. *Upper layers of trees with roots, in stream-tin sections, and submerged forest-bed of coast:* re-emergence of the land; considerable forest-growth; climate genial.
5. *Upper Peat and drifted wood, in estuarine deposits:* decay of trees; climate probably more humid than that of No. 4.
6. *Marine deposits* of present coast: recent advance of the sea.

The beds of the broad Fenland may be similarly arranged thus:—

1. *Lowest Buried Forest:* land more extensive than now; climate genial.
2. *Lowest Peat:* decay of forests; humid conditions.
3. *Marine Deposits:* submergence of the land to a depth of 30 feet or so below its present level.
4. *Second Buried Forest* (probably also *submarine forests* of Hunstanton, Skegness, etc.): re-emergence of land; return of genial climate.
5. *Upper Peat:* decay of second forest; humid conditions.
6. *Marine Deposits, Peat, Shell-marl,* and *Newer Forest-beds:* recent submergence of the land; shallow lakes; humid conditions giving rise to growth of peat; now and again small trees make their appearance in such parts of the Fenland as become sufficiently dry; the area of land slowly increasing, owing to marginal accumulations of marine silt.

Since the Postglacial and Recent deposits of these separate districts agree so closely, the conviction is forced upon us that such close parallelism cannot be the result of mere local circumstances, but must be due to the prevalence of similar conditions over a wide region. In each of the districts referred to we have evidence, first, of a considerably broader land-surface than the present, when the climate was favourable to an abundant growth of forest-trees. Then, in the second place, we have proof that those genial conditions were succeeded by a period of greater humidity, during which the forests decayed, and were gradually overgrown by marsh-plants. It is remarkable that the decay of the forests and the growth of the peat were accompanied and succeeded by a limited submergence of the land, during which marine deposits gathered over the surface of the vegetable accumulations. And it is not less worthy of note that the subsequent emergence of the land and its elevation to a higher level than the present, was followed or accompanied by a return of genial conditions, when great forests gradually spread over what are now low maritime regions. Eventually this genial climate gave way as before to more humid conditions; the forests decayed and marsh-plants luxuriated above them, while at the same time the sea again advanced upon the land, although not to such an extent as during the previous period of submergence. Since that last movement the relative level of land and sea has apparently experienced little change. In some places, however, the waves and tides have caused the coast-line to recede, while in other regions there has been a gradual silting-up of the sea. The oldest of the buried forests has yielded, as we have seen, relics of Neolithic age, and similar remains occur even at higher levels. It is only when we come to the upper buried forests and peat, however, that remains of Celtic and Roman times make their appearance.

Raised-beaches of Postglacial and Recent age are met with now and again at low levels upon the English coast, and some of these have already been referred to. Such, for example, are the marine deposits overlying the lower buried forests, and the inner margins of which are sometimes as much as 25 feet or even 30 feet above the present sea-level. None of the postglacial raised-beaches appears to attain a greater elevation than this. The old sea-margins, which occur at higher levels, belong to the Pleistocene series; they all date back to a time anterior to the growth of the lower buried forests of the north-western, southern, and eastern counties, and have already been briefly described.[1]

In the inland districts peat-bogs and Postglacial and Recent alluvia occupy relatively the same geological position as similar accumulations in Scotland. In the hilly regions of the north and in Wales they overlie the latest deposits pertaining to the Glacial Period; in East Anglia and the south-eastern region generally they likewise rest upon accumulations of Pleistocene age. Thus, in the valley of the Thames and other streams, we find tracts of low-level alluvial land bordering the rivers, all of which belong to postglacial and recent times, as is proved by the fact that they have often yielded remains of the true postglacial fauna along with relics of Neolithic and later ages. But what is chiefly noteworthy about those alluvia is this—that in Lincolnshire and neighbouring districts they everywhere overlie unconformably the more ancient accumulations of gravel, sand, and loam, in which occur the relics of Palæolithic man and the remains of Pleistocene fauna. A good example of this has already been pointed out as having been ascertained by Mr. Skertchly in the Fenland. No one, indeed, can traverse the counties of Norfolk and Cambridge without observing that while deposits of Palæolithic age occur frequently on hill-slopes, and even sometimes extend across watersheds, all the modern alluvia are confined entirely to the bottoms of the valleys. In such valleys as the Thames, the latter form in like manner the low-lying plains through which the rivers flow, and invariably overlie the true Pleistocene deposits.

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[1] For notices of submarine forests and peat, and raised-beaches of Postglacial age, see (for southern counties from Cornwall to Kent)—*Phil. Trans.*, vol. l. p. 51; De la Beche: *Rep. Geol. Corn., Dev., and West Som.*, p. 419; *Trans. Roy. Geol. Soc. Corn.*, vols. i. p. 236; iii. p. 166; iv. p. 481; vi. pp. 23, 51, 230; vii. pp. 35, 62; *26th Ann. Rep. Roy. Inst. Corn.*, p. 36; *40th Rep.* (of same), pp. 17, 31; *Jour. Roy. Inst. Corn.*, No. xiii. p. 77; (see also for copious references to stream-tin sections Mr. Ussher's papers in *Geol. Mag.*, Dec. ii. vol. vi., and his *Post-Tertiary Geology of Cornwall*); *Trans. Dev. Assoc.*, 1865, part iv. p. 30; 1866, part v. pp. 77, 80; 1868, vol. ii. p. 415; 1869, vol. iii. p. 127; vol. vi. p. 232; De la Beche, *op. cit.*, p. 417; *Proc. Geol. Soc.*, vol. ii. p. 599; *Quart. Journ. Geol. Soc.*, vols. iii. p. 249; vii. p. 118; xiii. p. 64; *Brit. Assoc. Rep.*, 1864, p. 63; 1867, p. 59; *Geol. Mag.*, vol. vii. p. 164; Dec. ii. vol. ii. p. 239; Lyell's *Principles of Geol.*, vol. i. chap. xx.; Chambers's *Ancient Sea Margins*, p. 240; Peacock's *Phys. and Hist. Evidences of Vast Sinkings of Land, etc.; Explanation of Geol. Survey Map*, Sheet 40, p. 4. For Channel Islands, see *Proc. Geol. Soc.*, vol. ii. p. 578; *Quart. Journ. Geol. Soc.*, vol. vii. p. 131; *Brit. Assoc. Rep.*, 1849, p. 51; 1867, p. 70; Peacock, *Op. cit.* For Eastern Counties, see *Brit. Assoc. Rep.*, 1858, pp. 111, 113; 1875, p. 82; *Mem. Geol. Survey*, "Geology of Middlesex," p. 95; *Geol. Mag.*, vols. iii. p. 62; iv. p. 560; v. p. 215; vi. p. 385; viii. p. 186; Dec. ii. iii. p. 491; v. p. 351; *Quart. Journ. Geol. Soc.*, vols. xxii. p. 564; xxvii. p. 237; *Phil. Trans.*, vols. xxii. p. 980; lxxxix. p. 145; *Proc. Roy. Geol. Polyt. Soc. West Rid. York.*, vol. iii. p. 637; Porter's *Geol. of Peterborough;* Miller's and Skertchly's *The Fenland*, p. 566; "The Geology of the Fenland," *Mem. of Geol. Surv. Engl. and Wales;* Rev. G. Munford on "Submarine Forest of Hunstanton," quoted by Lucy in *Proc. Cotteswold Club*, 1874; Howse, in *Proc. North of Engl. Inst. Mining Engineers*, 1864. For Western Counties and Wales, see *Proc. Geol. Soc.*, vol. i. p. 407; *Quart. Journ. Geol. Soc.*, vols. xii. p. 169; xxii. p. 1; xxvii. p. 655; xxxiv. p. 447; *Proc. Geologists' Assoc.*, vol. iv. No. 4; Hume's *Ancient Meols*, etc. (1863), and *Supplement* (1866); *Geologist*, 1864, p. 216; *Geol. Mag.*, vols. ii. p. 382; iii. p. 289; v. p. 352; vi. p. 72; vii. p. 337; ix. p. 111; *Explanation of Geol. Surv. Map*, Sheet 90, S.-E.; *Proc. Cotteswold Club*, 1874, p. 105; Chambers, *Op. cit.; Brit. Assoc. Rep.*, 1854, p. 80; *Proc. Geol. Soc. Liverpool*, 1871-72, p. 73; 1872-73, p. 42; 1875-76, p. 120; *Trans. Geol. Soc. Manchester*, vols. xiii. p. 71; xiv. p. 238.

As in Scotland, so in England, evidence is not wanting to show that in early postglacial times the rivers must have flowed in larger volume than at present. In the northern districts, and in Wales especially, the river-gravels of the upper valleys are often comparable with the similar accumulations in the hopes and dales and glens of the Scottish Uplands and Highlands. They tell of streams that more frequently than now assumed a torrential character, and I can hardly doubt that it will eventually be found that some of the small moraines in the higher valleys of the northern Lake District and of Wales really belong to Postglacial and Neolithic times.

Of lacustrine alluvia and peat-bogs there is little more to be said. They resemble in all essential features the similar accumulations in Scotland. In many of the ancient silted-up lakes considerable beds of marl and plentiful remains of the postglacial fauna have been met with, while the peat-mosses have yielded abundant relics of a bygone Age of Forests. From the facts revealed by the submarine forests. which occur upon at least two horizons, we need feel no surprise to learn that the peat-bogs of the inland districts now and again contain successive tiers of forest-trees. At the bottom of the bogs, oak or pine, or both, usually occur—the pine occupying the higher levels and more gravelly soil. Higher up in the peat appears a second stratum of timber, consisting chiefly of birch and hazel, but sometimes principally of oak ; and a third buried forest is occasionally found a little higher up, the common tree in which is generally alder or willow.

Some twenty years ago Mr. Pengelly discovered *Betula nana* in the freshwater deposits at Bovey Tracey, in Devonshire, and Professor Heer identified other plants, obtained by Pengelly from the same locality, as willows—*Salix cinerea* and *S. repens?* The latter he now thinks is more probably *S. myrtilloides.* Mr. Nathorst has more recently examined the beds and obtained *Betula nana, B. alba, Salix cinerea,* and other willows, *Arctostaphylos uva-ursi*—the last-named being a species which does not come farther south than Cumberland and Yorkshire, while *Betula nana* is confined to the Scottish mountains.[1]

The postglacial mammals of England, exclusive of those which are still indigenous, are brown bear, great Irish deer, elk, reindeer, urus, long-fronted ox, aurochs or bison, otter, beaver, wolf, and wild-cat. Of these, the brown bear was a native of England during and probably for some time after the Roman occupation. The beaver had become scarce in Wales before the close of the ninth century, for we find in the Laws of Hywel Dha, where the prices of furs were regulated, that a marten's skin cost 24d., an otter's 12d., and a beaver's 120d. It was still existing, however, towards the close of the twelfth century, and is mentioned by Giraldus Cambrensis as being at that time a native of Wales. The wolf appears to have been extirpated in the north of England in the reign of Henry VIII. The urus and the long-fronted ox probably ceased to be feral in early historic times. The reindeer, the elk, and the great Irish deer belong to an early postglacial age, and seem to have become extinct in England in days probably long anterior to the Roman invasion. The mammoth is generally excluded by geologists from the post-pleistocene fauna of Britain. Its remains, however, have certainly been recorded from what seem to be true post-pleistocene or postglacial deposits.[1] It is doubtful, however, whether these recorded instances can always be depended upon. But although the few remains which have at rare intervals turned up may in some cases be derivative—that is to say, washed out of older deposits and re-imbedded in postglacial alluvia and peat, yet this will hardly account for the occurrence of the two perfect heads of the mammoth in the peat at Holyhead, in Anglesea, nor for the peat-stained molar, which came from the submerged forest of Torbay. Neither Sir Charles Lyell, Dr. Falconer, nor Mr. Pengelly had any doubt about the matter, but were of opinion that the mammoth survived in England down to the period when the so-called submarine forests were growing. The heads referred to lay two feet below the surface, in a bed of peat which was covered with stiff blue clay, and formed the shoreward prolongation of the submarine forest and peat which were observed at low-water in the harbour by the Hon. W. Stanley. Some of the other instances are not perhaps so remarkable, and might be "explained away." It is worth note, at all events, that the discoveries appear to have been made in deposits either at or below the present sea-level. Nowhere, so far as I know, have mammoth-remains been detected in any of the post-pleistocene or postglacial deposits of the inland districts. It might be supposed, therefore, that the teeth and tusks which have been found here and there in postglacial deposits bordering upon the sea are possibly derivative. Had the mammoth occupied England in postglacial times, surely we might have expected to meet with its remains in alluvia and peat-deposits like those of the Kennet valley, where the postglacial fauna is so well represented. This, however, is after all only negative evidence. It may be that the mammoth did re-visit England, in greatly diminished numbers, perhaps, in postglacial times, and that its general absence from the deposits of the period in question may be thus accounted for.[1] It is not without significance that remains of the reindeer likewise occur very sparingly in postglacial deposits, and it does not appear to have been hunted in England or similar latitudes on the Continent in early Neolithic times. It is pretty certain, indeed, that the arctic fauna had disappeared from Middle and Western Europe before the advent of Neolithic man. The reindeer and its northern congeners retired to their present homes across the area vacated by the great *mer de glace* of the last cold epoch of the Glacial Period. The question is, did the mammoth also migrate northwards in postglacial times, and become extinct in North-western Europe before the approach of the Neolithic people? At present we cannot assert that it did not follow the reindeer—on the contrary, such evidence as we have would lead one to infer that it did re-appear in England in post-pleistocene or postglacial times, but probably became locally extinct before the commencement of the Neolithic age. I say *locally extinct*, because it is hard to believe that the complete carcasses found in the frozen earth of Siberia can date back to so remote a period as the Pleistocene and early Postglacial. Be this, however, as it may, it seems to me quite an open question whether the mammoth may not have survived in Europe the last cold epoch of the true Ice Age, and the deposition of the valley-löss of the great continental rivers.

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[1] See *Philosophical Transactions,* 1862, p. 1039, and *Öfver. af K. Vet.-Akad. Förh.,* 1873, No. 6, p. 17.

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[1] See Lyell's *Principles of Geology*, vol. i. 11th ed., p, 550 ; *Trans. Tyneside Naturalists' Club*, vol. v. p. 111 ; *Trans. Devon. Assoc.*, vol. iii. p. 143 ; iv. p. 455 ; v. p. 39 ; vi. pp. 232, 683 ; ix. p. 84.

The submarine forests and peat, and the Postglacial and Recent raised-beaches of Ireland, being of the same nature as those of England and Scotland, do not call for special description. They are generally more or less well developed where the coast-land is low and shelving, but they appear seldom or never to afford sections so detailed and complete as those of Lancashire, Cornwall, and the Fenland. Submarine forests and peat occur most frequently on the east and south coasts, along the shores of sandy bays, where they are exposed at low-water. They testify generally to a considerable loss of land within some recent geological period, and in certain places they even yield evidence of several successive oscillations of the sea-level. Thus, at Tramore Bay, County Waterford, there is a raised estuarine deposit which, according to Mr. Hardman,[1] shows the following succession of beds :—

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[1] It would appear to be equally rare in the postglacial alluvia and peat of the Continent. The only instance which I know of is that of a molar which was found under the peat-bog of Eelde, in the Province of Drenthe (Holland). The same bog has yielded horns of an ox (*Bos priscus?*). Tegenwoordige: *Staat van het Landschap Drenthe*, p. 340. It is possible that the molar may be derivative in this case.

1.	Bog or peat, passing in parts into alluvium.	
2.	Upper gravel-bed, with sea-shells . . .	0 to 8 ins.
3.	Dark peaty sandy layer (shells abundant at base)	1 ft. to 2 ft.
4.	Lower gravel-bed ; shells very abundant . .	3 ins. to 2 ft.
5.	Blue mud-layer, with fragments of wood, extending into cracks in (6)	2 ins. to 2 ft.
6.	Gravelly brown boulder-clay.	

The boulder-clay, Mr. Hardman thinks, has evidently been denuded by running-water at a time when it formed an old land-surface. Then came a period of submergence, when the beds 5 and 4 were deposited. The shell-beds contain the common littoral species, cockle, mussel, periwinkle, etc., and extend to a height of ten feet or thereabout above high-water mark. After the formation of the shell-beds the sea retreated to a lower level, and the accumulation of bed No. 3 ensued. This is a dark, sandy accumulation, abundantly charged with the *débris* of land-plants, and is probably, as Mr. Hardman says, an old alluvium or freshwater deposit in part ; it passes, however, horizontally into true peat, and there can be no doubt, therefore, that it indicates an ancient land-surface. The presence of the overlying bed, No. 2, which contains cockles, proves another submergence, but apparently of limited extent, for this upper shell-bed does not go higher than 2 or 3 feet above high-water. It is overlaid by bog or peat of quite recent formation, which passes into alluvium along the course of the Keiloge river, but is liable to be flooded at spring-tides, showing, as Mr. Hardman is inclined to think, still more recent oscillations of the sea-level. If, now, we tabulate these results, we have the following succession of changes :—

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[1] *Geol. Mag.*, Dec. ii. vol. i. p. 210.

1. Land-surface of wider extent than present.
2. Submergence of land to a depth of not less than ten feet below the present limits of high-water.
3. Retreat of the sea ; land of wider extent than now.
4. Re-submergence of land, not reaching more than two or three feet below present high-water mark.
5. Retreat of the sea ; wider land-surface.
6. Perhaps a very recent change of sea-level ; sea advancing.

Amongst other examples of submerged trees and peat upon the coasts of Ireland are those of Wexford Harbour, Youghal Harbour, Clonea near Dungarvan, Courtmacsherry Bay, Dunworley Bay, Tralee Bay, and Kilcredane Point, at the mouth of the river Shannon.[1] Raised-beaches are also well developed, the two lowest corresponding probably to the two postglacial raised-beaches of Scotland. The upper one occurs at an average height of about 35 feet or more above the mean level of the sea round Ireland ; the lower one at about 20 feet above the same datum-line. But their heights vary according to the position of the terraces, which in the estuaries and some of the bays tend to rise to a somewhat higher level, just as we found was the case with the raised-beaches of Scotland. The lower terrace, being the more recent, is necessarily better marked than the other. It is of variable breadth, and often backed by cliffs, at the base of which appear old sea-worn caves ; while isolated stacks of rock rise up from the terrace itself. Here and there natural and artificial sections reveal the structure of the raised-beach, which in some places is largely composed of gravel and sand, containing a rich variety of shells belonging to species that are still common to British seas. In these shell-beds flint implements of Neolithic types have been obtained in large numbers, especially at Kilroot, on the coast of Belfast Lough. In other places similar finds have been met with, as in the raised-beaches of Carlingford Bay. Again, on the coasts of Meath and Dublin remains of kitchen-middens, with traces of fireplaces, have been detected in such positions as to show that at the time the shells were being gradually heaped up by the coast-dwellers of Neolithic times, the land stood relatively at a lower level. The upper beach appears to be likewise pretty well developed in some places, and it has also yielded flint implements and other traces of man's presence.[1]

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[1] See *Mem. Geol. Survey Ireland:* Explanation of Map, Sheets 104, 113, 103, 102 ; Sheets 140, 141, p. 16 ; Sheets 160, 161, 171, 172, p. 49 ; Sheets 194, 201, 202, p. 27 ; Jukes's *Manual of Geology,* 3d edit. p. 740 ; Kinahan's *Geology of Ireland,* p. 264.

The great peat-bogs of the interior have almost everywhere yielded relics of the forests of postglacial times. Mr. Kinahan says that "usually the roots and trunks of the trees under the peat or in the lowest strata are principally those of the oak and yew, as if, prior to the growth of the peat, the low country was a vast forest of these trees."[2] Higher up in the bogs, at a distance of 4 to 12 feet above the oak-trees, occurs a second layer of stumps and trunks, consisting chiefly of pine. And this upper forest is in like manner buried under peat. In the lowland bogs of the west of Ireland both the forest-layers occasionally consist of pines, and the same is the case in many of the bogs of the mountainous districts, as if in such places, Mr. Kinahan remarks, there had been two distinct ages of deal forests. According to the same geologist, the succession of changes which these facts attest is as follows:—1st, There was a time when great forests of oak and yew covered the country, the oak growing on the hills up to a height of 400 feet or thereabout above the sea; while at higher levels deal was the prevailing timber, flourishing at greater heights than now, as is shown by the occurrence of large trunks in bogs at elevations above 1000 and 1200 feet. 2d, Subsequently mosses and other peat-producing plants began to grow and flourish, stopping the drainage, killing the trees, and gradually enveloping them as they fell. 3d, In this manner the low grounds became disforested over wide areas, wherever, indeed, the peat could easily accumulate; but on low hills, in the bogs, the oak still continued to grow. 4th, By and by the growth of peat ceased, and forests, principally of deals, sprang up on the peaty surface, and continued to flourish for a long time contemporaneously with the oaks that covered the hills or "islands" in the bogs. These hills, Mr. Kinahan says, "although now destitute of trees, are still called *derrics* (Anglicè, *oak-woods*), the ancient name, which has survived down to the present day, probably from the time when they were oak-groves, surrounded by forests of deal. In some of the wilds of Mayo the oak may still be found growing on the drift-islands in the bog, it always being associated with yew, hazel, birch, ash, and holly; probably the last three kinds of trees were also denizens of the primary forests, but their timber has long since disappeared, they being of kinds that rot quickly in the bogs." 5th, A second epoch of peat-growth succeeded, during which the deal forests succumbed in the same manner as the oaks had done at an earlier period.

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[1] For accounts of raised-beaches, see Hull's *Physical Geology and Geography of Ireland*, p. 107; Kinahan, *op. cit.* p. 251; *Brit. Assoc. Rep.*, 1834, p. 658; 1852, p. 43; 1872, p. 113; 1874, p. 74; *Quart. Journ. Geol. Soc.*, vol. xxiv. p. 4; *Geol. Mag.*, vols. iv. p. 8; x. p. 453; Dec. ii. vol. i. p. 210.

[2] *Op. cit.* p. 268. The details that follow are taken from the same work.

Human relics have frequently been discovered in the Irish peat-bogs. Mr. Kinahan mentions the occurrence of a two-story log-house under 14 feet of peat in Drumkelin Bog, Inver, County of Donegal. It rested upon a thickness of 15 feet of peat, making in all 37 feet, "over 22 feet of which must have grown around and above the house since it was inhabited. On a level with the floor of the house were the corkers (stumps) of sallow, ash, and oak; while in its vicinity a piece of a leather sandal, a flint arrow-head, and a wooden sword, were subsequently found." Human bodies, clad in woollen and hair garments of antique fashion, have also been now and then discovered at various depths in the bogs. Old roadways, formed of timber, have likewise been observed. In one case (Duncan's Flow-bog, Ballyalbanagh, County Antrim) an ancient roadway, constructed of oak, occurred at a depth of 15 or 20 feet, and rested upon 4 feet of black turf, at the base of which stumps and logs of oak appeared. The oak-timber of the roadway was probably procured, as Mr. Kinahan suggests, from the neighbouring upland. On the same level as the road, stools and logs of deal make their appearance; and since holes in the wooden pavement have been mended with deal slabs placed across them, it may be inferred that the path continued in use up to the time when the deal forest had begun to flourish over the dried peat-bog. "The road seems to have been abandoned and the deal forest destroyed at the same time, which appears due to flooding, as the peat above both is 'flow-bog' (Ulster), that is, peat full of sedge and flaggers, which only grow or accumulate in marshes or flooded bogs." Another example of the same kind of ancient roadway, formed of oak-timber, is that met with in a bog near Castle Connell, County Limerick. Near the path there was found a keg, full of a substance like whey, standing beside an oak-stump. Above this level came 5 feet of peat, to which succeeded a buried forest of deals, covered in its turn by more than 12 feet of bog. Another very interesting series of antiquities are the famous "crannoges" or lake-dwellings of Ireland, some of which date back probably to Neolithic times, while others were occupied down to a recent historic period. And the same appears to be true of the kitchen-middens, which occur at various places upon the coasts. Both the Neolithic and the Bronze Ages are represented by great numbers of implements, arms, and ornaments, which are met with generally over the whole island—sometimes in peat, sometimes in alluvial deposits, and at other times lying loose at the surface.

The animals which occupied Ireland in Postglacial and more Recent times include red-deer, reindeer, great Irish deer, long-faced ox (*Bos longifrons*), goat, sheep, wolf, fox, dog, bear (*Ursus spelæus* or *U. ferox*), etc. Of these the most characteristic, by reason of its great abundance, is the Irish deer, remains of which are very common in the marl and clay under the bogs.

CHAPTER XX.

POSTGLACIAL AND RECENT DEPOSITS OF THE CONTINENT.

Postglacial and Recent deposits of Norway and Sweden—No direct passage from Glacial into Postglacial accumulations — Postglacial shelly clays, etc. — Character of the molluscan fauna—Contrast between shelly clays of the east of Sweden and those of Western Sweden and Norway—Height of Swedish and Norwegian shell-banks above sea-level — Postglacial freshwater and marine deposits of Finland—Unfossiliferous clay and sand above shelly clays of Norway and Sweden—Postglacial erratics resting on shelly clays of Eastern Sweden—General conclusions—Submerged peat of Scania—Raised-beaches of same region—Submerged peat and trees of Denmark; of Schleswig-Holstein; of East Friesland and Holland; of Flemish coast; of Somme Valley; of Normandy and Brittany; of Arcachon and Biarritz—Age of the submerged forests of the Channel area—Peat-bogs of Denmark; of Norway—Rate of growth of peat—Arctic flora in Postglacial deposits of Southern Sweden, of Brandenburg, and other parts of Germany—Peat of Champagne, its organic remains—Peat-bogs in other regions of Europe—No trace of Palæolithic man in any Postglacial accumulations—Postglacial deposits of Spitzbergen.

The Postglacial and Recent deposits of the Continent assume their most interesting development in Scandinavia. In that region, as in our own islands, the occurrence of well-marked marine deposits pertaining to the Postglacial Period supplies us with a line of evidence which, of course, is entirely wanting in the interior of the Continent. And, as I shall point out in the following chapter, it is from the marine accumulations of North-western Europe that a large part of postglacial history has to be constructed. My account of the Scandinavian deposits must therefore be considerably more detailed than that of their equivalents in other parts of the Continent.

In the low grounds of Southern Scandinavia the glacial clays with their arctic fauna are overlaid directly with marine deposits of postglacial age, which frequently cover a wide extent of country. These consist principally of clay and beds of shells, sand, and gravel, and they prove that in postglacial times the southern parts of Norway and Sweden were submerged to the exent of 350 feet at least. The depth of the submergence, however, must have been actually more. Thus in Norway and Sweden the highest shell-banks occur at a height of 150 feet above the sea, to which we must add 90 feet or thereabout to allow of sufficient depth of water for the shell-fish to live in, since they could not have existed at the actual high-tide mark. This will give us a former submergence of 240 feet. Postglacial shelly clays, however, attain a greater elevation than is reached by any of the shell-banks. Kjerulf states that clays with shells reach a height in Norway of 250 to 380 feet, and he would allow 20 or 30 fathoms for the depth of water in which those clays accumulated, which would give a submergence of 370 to 560 feet.[1] This agrees sufficiently well with the conclusions arrived at by the Swedish geologists, Professor Erdmann stating that the Postglacial clays of Sweden reach a height of 200 or 300 feet, and perhaps more. The old shore-lines of the postglacial sea are frequently marked out by littoral accumulations —by heaps of sand and gravel and shells, which begin at 150 feet and occur at many different levels down to some 50 feet above the sea.[2]

It is remarkable that no direct passage can be traced from the true glacial shell-beds into those of postglacial age. The latter everywhere appear to rest unconformably upon the former. We leave the glacial clays stocked with the remains of a strongly-marked arctic fauna, and are confronted in the overlying postglacial beds by a fauna which is distinctly temperate, and approaches in character to that which now occupies the adjacent sea. We shall by and by endeavour to discover the meaning of this apparently abrupt transition from arctic to temperate conditions, but in the meantime we must look a little more closely at the leading characteristics of the postglacial beds. The beds in question consist of three more or less well-marked divisions or groups, which, beginning with the lowest-lying or oldest, are as follow:—

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[1] *Udsigt over det sydlige Norges Geologi*, p. 3,

[2] *Exposé des Formations Quaternaires de la Suède*, p. 91.

1. Dull brown and dark blue clay, with shells and associated banks of sand, gravel, and shells.
2. Light gray and pale brown clay, with no organic remains.
3. Sand unfossiliferous, with which are not unfrequently associated erratics.

The lower shelly clay (No. 1) is well developed along the low-lying maritime districts, where it seems to cover the ground as a somewhat continuous sheet. It follows all the sinuosities of the coast-line, and thus penetrates for a greater or less distance into the interior of the country. It is likewise commonly met with cloaking the bottoms of valleys that open directly upon the sea, and can be traced along the margins of certain lakes which in late glacial and postglacial times were arms and gulfs of the North Sea and the Baltic. In some places this clay is highly fossiliferous, and has yielded a very rich variety of shells, in which respect it offers a striking contrast to the glacial clays, characterised as these are by a much scantier assemblage of species and individuals. Most of the postglacial species still inhabit the neighbouring seas, but many of the shells are smaller than those of the same forms that occur in the glacial deposits. A few northern species, which are very common in the latter, reappear in diminished numbers in the postglacial beds. Among these are *Yoldia pygmæa* var. *gibbosa*, *Tritonium Sabinii*, *Rhynconella psittacca*, *Cardium elegantulum*, and *Margarita costulata*, none of which now lives south of Lofoten and Finmark.[1] On the other hand, the well-known species of the southern coast of

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[1] The following species, which are very abundant and characteristic forms in the Norwegian shell-banks of Glacial age, are feebly represented in the Postglacial shell-banks:—

In Glacial shell-banks.	In Postglacial shell-banks.
Pecten islandicus (Müll.) . . .	Becoming rare.
Mya truncata (Linn.) . . .	Becoming thinner in the shell.
Saxicava rugosa (Linn.) . . .	Do. do.

Norway, which are wholly wanting in the true glacial beds, appear abundantly in the postglacial deposits. It is remarkable, however, that some molluscs which in postglacial times lived in great numbers on the south coasts of Norway have now retired to the west coast (*Kellia rubra* [Cardium], Mont., *Tapes virginea* [Venus], Mont.); some to the same and the north coast (*Lima excavata* [Ostrea], Fal., *Pecten islandicus*, Müll., *P. vitreus*, Chemn., *Pholas crispata*, Linn., *Margarita undulata*, Sow.) A few species (*Cæcum glabrum* [Dentalium], Mont.)[1] which occur very abundantly in the shell-banks at Kirköen in Norway have hitherto only been found living on the west coast (Bergen), and are there somewhat scarce. Malm, however, notes *Cæcum glabrum* as still living at Bohuslän (Sweden). The elder Sars, to whose papers[2] I am chiefly indebted for these notes, draws

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In Glacial shell-banks.	In Postglacial shell-banks.
Buccinum grœnlandicum (Chemn.)	Represented by *B. undatum* (Linn.)
Trophon clathratus (Linn.), var. *major*	Do. *T. clathratus*, var. *minor.*

The Glacial are similarly contrasted with the Postglacial clays, thus :—

In Glacial marly clay.	In Postglacial shelly clay.
Yoldia arctica (Gray)	Wanting.
Siphonodentalium vitreum (Sars)	Do.
Dentalium abyssorum (Sars)	Scarce.
Arca raridentata (Wood), var. *major*	Extremely scarce.
Leda pernula (Müll.)	Do.
Yoldia pygmæa (Münst.), var. *gibbosa* (Smith)	Do.
Natica grœnlandica	Do.
Nucula tenuis	Wanting.

The foregoing species are all highly characteristic of the Glacial beds. Again, the most characteristic deep-water forms of the Glacial and Postglacial clays are as follow :—

Glacial marly clay-beds.	Postglacial shelly clays.
Yoldia pygmæa, var. *intermedia.*	*Isocardia cor* (Linn.)
Leda pernula.	*Cardium elegantulum* (Beck).
Nucula tenuis.	*Neæra cuspidata* (Olivi).
Arca raridentata, var. *major.*	*Rhynconella psittacea* (Gmelin).
Siphonodentalium vitreum.	*Waldheimia septigera* (Lovén).
Dentalium abyssorum.	
Ophiura Sarsii (Lüth.)	

[1] Sars mentions also *Odostomia plicata*, but according to Jeffreys this is a wrong determination, and should be *O. albella*, which ranges from Norway to the Mediterranean.—*British Conchology*, vol. iv. p. 122.

[2] See especially “Iagttagelser over den postpliocene eller glaciale Formation,’

attention to the occurrence in the postglacial beds of *Tapes decussatus* [Venus], Linn., a mollusc which, he says, does not now occur on the Norwegian coast, but is distributed from the Mediterranean to England. In the postglacial deposits the shells of this species are as large as those of the largest living specimens in the Mediterranean. Quite recently, however, this mollusc has been found by G. O. Sars living on the west coast at Bergen. Another species (*Pholas candida*, Linn.) mentioned by Michael Sars as having now apparently retired south from the Norwegian coast has since been met with by Lovén. Jeffreys says it ranges from Iceland and Norway to Algeria, Sicily, and the Black Sea. Many of the shells, indeed, which are most abundant in the postglacial deposits of Sweden and Norway, where they occur commingled with arctic and boreal species, are, as Jeffreys remarks,[1] of rather a southern type. Such are *Ostrea edulis, Tapes pullastra, Corbula gibba, Aporrhais pes-pelicani,* and some already mentioned. And, according to Michael Sars, the mollusca of the Norwegian postglacial beds comprise 175 species, of which 75 are arctic, 59 boreal, and 41 Lusitanian-Mediterranean. The same naturalist has also pointed out that perfectly-identical species are found living in the North Sea and the Mediterranean, although they have not been met with upon the intervening coasts of the Atlantic.[2] From these facts he has inferred that some communication between the North Sea and the Mediterranean must have existed across the low grounds of Europe at a comparatively recent geological date. But, as we shall afterwards see, the facts admit of another and more probable explanation.

The postglacial clays which occur in the east of Sweden present a strong contrast to those of Western Sweden and

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by Sars and Kjerulf, *Universitets-program* for 1860, I., and "Om de i Norge forekommende fossile Dyrelevningar fra Qvartær Perioden," etc., by M. Sars, *Universitets-program*, 1864, I. A translation of the first of these papers will be found in *Edinburgh New Philosophical Journal*, vol. xviii., New series, p. 1.

[1] *British Association Reports*, 1863, p. 74.

[2] Sars mentions *Nephrops norvegicus*, L.; *Lota abyssorum*, Nilss.; *Sebastes imperialis*, Cuv.; *Macrourus* (*Lepidoleprus*) *cœlorhynchus*, *Cerithium vulgatum*, Brug.; and *Monodonta limbata*, Phil.

Southern Norway, in the poverty of their organic remains. They have yielded only five species of molluscs (*Mytilus edulis, Cardium edule, Tellina balthica, Paludina balthica, Littorina litorea*), all of which with one exception (*Littorina litorea*) still occupy the brackish waters of the Baltic. The occurrence in the same deposits of the common bullhead (*Cottus scorpius*), which belongs to the littoral fauna of the Baltic, near Upsala, and even so far in the interior as Skattmansö, sufficiently demonstrates that the "black-clay" (*Svartlera*) of that region is a littoral and estuarine formation.

Now and again the postglacial clay becomes so abundantly stocked with shells, that these may be said to form the major portion of the deposit. Such shell-banks are frequently found in Southern Sweden reposing upon the slopes of certain great ridges of gravel called *åsar*, which are of true glacial age. Erdmann makes special reference to a shell-bank which cloaks the slopes of the *ås* or gravel-ridge of Enköping. This shell-bank is not more than 100 feet above the level of the sea, and has all the appearance of being a littoral accumulation, consisting as it does of rapid alternations of gravel, sand, clay, and triturated *débris* of the common mussel and *Tellina balthica.* But the chief point of interest about it is the occurrence in the clay-layers of plentiful remains of land-plants, such, for example, as the stalks of *Equisetum limosum*, leaves of the oak, the willow, the aspen, needles and cones of the pine, twigs, branches, and bark of the fir, the aspen, etc. The Equisetum, which still grows abundantly along the shores of the Baltic, occurs without doubt in the place of its growth—the margin of the ancient sea—where its stalks became embedded year by year in the gradually-accumulating sediment. The other plant-remains had evidently been washed down from the old land by running-water.

The postglacial shell-banks in the western districts of Southern Sweden are often similarly grouped along the flanks of prominent *åsar*, but they never reach a greater elevation than 100 to 150 feet above the sea. Like those of the eastern region, they are true littoral accumulations. In Southern Norway similar shell-banks are found at various levels, from 50 feet or so up to 150 or 200 feet above the sea.

The postglacial beds of Finland and Northern Russia have been described by Krapotkin and Schmidt as consisting partly of freshwater and partly of marine deposits—the former being the older of the two series. After the retreat of the great glaciers, or *mer de glace*, the surface of the ground was left covered with extensive sheets of boulder-clay, and abundant spreads and heaps of erratics, gravel, and sand. The Gulfs of Finland and Bothnia are believed to have existed at the close of the Glacial Period as great freshwater lakes—the terraces which mark the ancient margins of the lakes being found, not only in certain inland districts, but also upon some islands in the Baltic (such as Mohn and Dago), at a height of 50 feet or so above the sea. These terraces yield freshwater-shells (*Limnæa ovata* and *Ancylus fluviatilis*), and similar terraces, indicating the former presence of ancient lakes at higher levels, have been traced in the interior of Finland up to a height of 150 feet. The whole region, which even now contains many lakes, seems at the close of the Glacial Period, or the beginning of Postglacial times, to have been covered over wide regions with extensive sheets of fresh water. In many cases the natural dams which held in these waters consisted of *åsar* or great gravel-ridges that were rendered water-tight by the mantle of loam and silty clay which often cloaks their slopes. The different levels occupied by the ancient lakes, as their confining barriers successively gave way, are marked by terraces eroded in the sides of the *åsar*.

It is remarkable that, notwithstanding the great height to which marine late glacial and postglacial deposits have been traced in Scandinavia, not a single sea-shell or any other evidence of glacial or postglacial submergence has yet been detected in the interior of Finland. Professor Lovén[1] and other

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[1] *Öfv. af Kongl. Vet. Akad. Förh.* 1861, No. 6. Professor Lóven instances the occurrence of certain arctic species which occur both in the Baltic and some

Swedish naturalists and geologists have shown that there is some reason to believe that during late glacial times the Baltic had direct communication with the Arctic Ocean, probably by way of the Gulf of Finland and Lakes Ladoga and Onega to the White Sea. Lake Onega, however, is said to be 280 feet above the sea, and not a vestige of marine glacial or postglacial deposits has been observed in its neighbourhood. The only evidence of postglacial submergence which has been noted by Russian observers consists of certain deposits of gravel, sand, and clay, which occur along the margins of the Gulfs of Bothnia and Finland up to a height of 50 feet above the sea. These deposits are charged with remains of the well-known Baltic fauna. It would seem, therefore, that the movement of depression, which in postglacial times carried down the southern area of Norway and Sweden to a depth below its present level of 500 feet or thereabout, died out northwards to such an extent, that in the northern gulfs of the Baltic the sea covered only a limited area of low ground in the maritime districts.

The shell-bearing deposits of Norway are overlaid, according to Kjerulf, by unfossiliferous accumulations of lighter-coloured

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of the Swedish lakes. Malmgren likewise gives a list of fish which are common to the Baltic and the Arctic Ocean — *Cottus scorpius*, *Cyclopterus lumpus*, *Zoarcus viviparus*, *Gadus morrhua*, *Pleuronectes platessa*, *P. flesus*, *Liparis barbatus*, and *Clupea harrengus*, var. *membras* (*Kritisk Öfversigt af Finnlands Fiskfauna* 1863, p. xi.) Some of these, such as the bullhead (*Cottus scorpius*), the sucker (*Liparis barbatus*), and the variety of the herring, appear to be confined to the northern reaches of the Baltic. It is thought that these species tell strongly in favour of a recent direct connection between the Baltic and the Arctic Ocean. Had they immigrated from the south into the Baltic it is supposed that inherited instinct would have led them to return by the same way when the conditions in the Baltic became less favourable. I must mention also that Lovén has noted the occurrence in the valley of the Dwina, to the east of Onega, of deposits with arctic shells which go up to a height of 150 feet. Still, although this evidence is suggestive it is not convincing. It may be that the arctic forms in the Baltic are simply relics of the fauna which lived over the submerged regions of Scandinavia during the deposition of the late glacial clays, when the Baltic was as salt as the open ocean, and characterised by the presence of *Yoldia* (*Leda*) *arctica* and its congeners. They would appear to come into the same category as those high northern forms which are still found lingering in the deeper depressions of the sea-bottom round our own coasts. The former direct connection of the Baltic with the Arctic Ocean has yet to be proved.

clay. Followed up from the maritime districts into the interior of the country, this deposit of clay is found to be continuous with lacustrine beds—accumulations of freshwater origin. At the lower levels of the land it is thicker and purer than in the inland districts, where it frequently contains layers and beds of fine sand. It is often covered by deposits of sandy clay and sand, in which boulders and erratics occur not unfrequently, especially towards the top of the series. In Sweden, likewise, the postglacial shelly clays are overlaid by a deposit of unfossiliferous sand (*mosand*), which covers as an almost continuous sheet wide areas in the low grounds.

Erratics also are often found perched upon the tops of the shell-banks or sprinkled over the surface of the shelly clays. Lyell has referred to the occurrence of some large masses of gneiss, 9 to 16 feet in diameter, which he observed resting upon one of the postglacial shell-banks in the neighbourhood of Upsala, and which seem to have impressed him as somewhat remarkable. He says, "Here we have proof that the transport of erratics continued to take place, not merely when the sea was inhabited by the existing testacea, but when the north of Europe had already assumed that remarkable feature of its physical geography which separates the Baltic from the North Sea."[1] We must not forget, however, that even in our own day erratics are transported by floating-ice in the Baltic,[2] so that the contrast between the present conditions and those that obtained at the time the Upsala erratics were dropped or stranded, is not so great as it might appear.[3]

From the facts which have been thus briefly summarised we gather that in postglacial times the southern part of the Scandinavian peninsula was submerged to the extent of 400 or

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[1] *Antiquity of Man*, p. 281.

[2] Untersuchungen über die Erscheinungen der Glacialformation in Estland und auf Oesel, *Bull. de l'Acad. Imp. des Sciences de St. Pétersbourg*, vol. viii.

[3] For descriptions of Scandinavian postglacial deposits, see Professor Erdmann's *Exposé des Formations Quaternaires de la Suède*, and papers by Professors Kjerulf and Sars in *Universitets-program* (Christiania) for 1860; by Sars, *Op. cit.* for 1864; by Kjerulf, *Op. cit.* for 1870; and, by same author, *Udsigt over det sydlige Norges Geologi*, 1879.

500 feet—there or thereabout. The temperature of the sea had been raised considerably above that of the cold waters in which the arctic fauna of the preceding Glacial Period had flourished, but, if we may judge from the continued presence, especially in the highest postglacial deposits, of certain northern forms, which have since vanished from the south of Norway and Sweden, the North Sea was still somewhat colder than at present. But as the land continued to rise, the temperature of the sea increased, and the fauna ere long entirely lost its arctic character. In short, the Postglacial Period merged into the Present.

Submarine peat occurs at many places along the low-lying and shelving shores of Scania. The peat is composed of numerous moorland- and marsh-loving plants of species which are still indigenous to the country, and it encloses roots, stems, branches, and leaves of various trees, such as oak, fir, birch, alder, and others, but never beech. There can be no doubt that this accumulation indicates an old land-surface, and since it passes out to sea it proves of course a recent submergence. Now and again the peat is overlaid along the margin of the sea by heavy masses of gravel and shingle which represent old beaches. Some of these gravel-banks rise 10 and 15 feet above the present sea-level, and are underlaid by deposits of postglacial silt and clay, containing marine shells of species that still live in the neighbouring waters. One of the most interesting raised-beaches is the great bank called Järavallen (or Gäravallen), which stretches as a more or less continuous ridge along the coast of the Baltic from Ystad to the part between Trelleborg and Falsterbo. Professor Nilsson tells us that underneath it in various places, there occur peat-bogs which lie below the surface of the sea. One of these bogs attains a thickness of 10 feet, 2 feet 5 inches of which lie above, and 7 feet 7 inches below the surface of the sea. "The turf under this stone wall is so compressed that when dry it is almost as hard as brown coal; the trees are also, like the layers of coal, pressed together, and when a fir-chip is broken it is found to be black and shining in the cross section, all the results of great pressure and of age. The turf has here, as in the submarine peat-bogs which lie outside Falsterbo, been formed in fresh water, of which the bottom when the turf was formed lay above the surface of the sea; inasmuch as in it were found the same species of shrubs as those that are found in the other Scanian peat-bogs, situated farther in the interior of the country. But on the bottom of this peat-bog, on the fine blue clay itself, there have frequently, during the cutting of the turf, been found *arrows*, *knives*, etc., of flint, which proves that human beings already existed in these districts at the time when the bog was an open water, and peat began to grow in it."[1] Nilsson further states that bones of a bear (supposed at first to be the great cave-bear, but since ascertained to be *Ursus arctos*) have been met with under this peat in association with human implements, and that the reindeer and the urus also occur in the oldest peat-bogs of Scania. Professor A. Erdmann has described a section across these remarkable deposits, and the succession of beds given by him is as follows:—

1. Gravel and sand of raised-beach.
2. Peat, 1 to 2 feet thick.
3. Clay with freshwater shells, 1 foot 5 inches.
4. Calcareous clay without shells.
5. Coarse glacial gravel.

In other places the peat is thicker and rests directly upon till or boulder-clay.

Similar beaches, as I have been informed by Mr. Törnebohm, are accumulating along the shores of north-eastern Scania at the present day, so that there seems no necessity for Nilsson's hypothesis of a violent rush of waters, caused by a sudden downward movement of the ground, to explain the formation of the Järavallen. The accompanying illustration kindly sent me by Mr. Törnebohm, will show the general features presented by the beach-gravels.

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[1] *The Primitive Inhabitants of Scandinavia*, p. 254. In connection with the occurrence of human relics in beach-deposits, I may refer to the discovery of a wooden hut at Södertelge, which has been cited by Lyell (*Antiquity of Man*, p. 282), as proving considerable oscillations of the sea-level within a recent period. It would seem that this is a mistake. The sand under which the hut was buried was not marine, but had slipped down from time to time from the steep slope of an *ås* or bank of glacial gravel and sand, at the foot of which the hut had been built. This view, Dr. Torell says, was advanced by Mr. Hisinger in 1840, in opposition to Lyell's explanation of the phenomena, and subsequent examination of the ground by Prof. Erdmann has confirmed Hisinger's general conclusion. See *Exposé des Formations Quaternaires de la Suède*, p. 109; and Torell, *Sur les traces le plus anciennes de l'existence de l'homme en Suède*, 1876, p. 14.

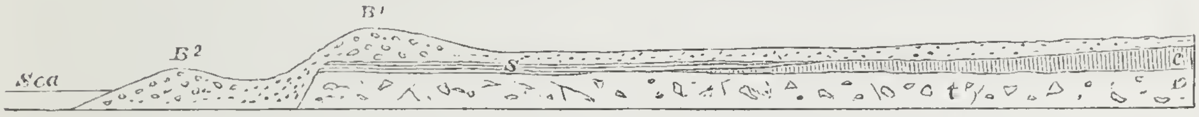

Fig. 13.—*t*, Till; *c*, Stratified glacial clay; *s*, Silt with recent shells; *B*¹, Old beach; *B*², Beach now forming.

Some interesting descriptions of raised-beaches on the coasts of Scania are given by Mr. E. Erdmann.[1] He mentions among others that which occurs near Helsingborg at a height of 10 to 15 feet above the present sea-level. The succession of beds in this beach he gives as follows:—

1. Beach-accumulations of sand and gravel with cockle- and mussel-shells, 3 feet to 3 feet 5 inches.
2. Peat, 5 inches.
3. Yellowish-gray silt with recent freshwater-shells, such as *Planorbis complanatus*, L., *Bithynia tentaculata*, L., *Limnæa limosa*, L., *β ovata-normalis*, etc., 1 foot 5 inches.
4. Peat with branches, stools, and roots of oak, 1 foot.
5. Loamy or clayey silt, freshwater, 1 inch.
6. Bluish-gray calcareous glacial clay, very thick.

At many other localities similar successions are met with at like low levels. Thus at Barsebäck, not far from Landskrona, at a height of 10 to 15 feet above the sea occur ancient sea-beaches which show the following structure:—

1. Beach-gravel and sand with *Mya truncata* and *Cardium edule*, 4 feet.
2. Decayed peat, 1 foot to 3 feet 5 inches.
3. Beach gravel.
4. Grayish-blue boulder-clay or till.

Mr. Nathorst has also made some recent additions to our knowledge of the raised-beaches which occur at low levels on the coasts of Scania.[1] The chief point of interest in all these beaches is the appearance of peat and freshwater beds which occur underneath banks and ridges of gravel and sand. These latter are unquestionably beach-accumulations, as is proved by the more or less abundant presence of rolled shells and shell-fragments belonging to familiar marine forms.

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[1] "Bidrag till frågan om Skånes nivåförändringar," *Geologiska Föreningens i Stockholm Förhandlingar*, Band i. No. 6.

Peat occurs under similar circumstances upon the opposite shores of Denmark, as in Jutland, and the Islands of Funen, Zealand, Möen, and Bornholm. On the west coast of Schleswig submarine peat is found at a depth of 30 feet below the present shore-line, and on the shores of Holstein and Hanover like phenomena make their appearance. According to Forchhammer[2] these peat-mosses indicate in certain regions a depression, and in others an elevation of the land. A line drawn from the middle of Nissumfjord in Jutland south-east to Nyborg in Funen, and passing south of Möen and Bornholm, marks out two regions in which Forchhammer thought the buried peat-beds tell different tales. South of this line, he says, they lie invariably below the present sea-level, and thus indicate a recent submergence of the land; to the north, however, the raised-beaches occurring at low levels give evidence of a recent movement in the opposite direction.

Upon the Prussian shores of the Baltic peat occurs at and below the sea-level, as at Gute Herberge near Danzig, where at four feet above the sea we find peat which varies in thickness from half-a-foot up to six feet. At Scharfenort the peat lies under sixteen feet of sand, and in the neighbourhood of Zipplau, at 20 feet over the sea, the following section is seen:—[3]

	Ft.	Ins.
Peaty soil	0	6
Peat	9	0
Clay, containing in places peat and decayed wood	4	6
Peat	1	0

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[1] "Om Skånes nivåförändringar."—*Op. cit.*, Band i. p. 281.

[2] "Om den forandrede Vandhöjde ved de danske Kyster."—*Nordisk Universitets-tidskrift* for 1856.

[3] *Neuerste Schriften der Naturforschenden Gesellschaft in Danzig*, Bd. iv. Heft iii., 1850.

In the summer of 1854 dredging operations in the bed of the river Elbe, near Blankenese, brought up great quantities of wood, pieces of amber, and freshwater-shells. The wood was chiefly oak, which was black in colour and approached in character to lignite.[1]

That a large part of Holland lies actually below the sea-level is rendered sufficiently evident by the presence of the great dikes which are maintained at such cost and trouble. Some writers maintain that this depression has resulted from the gradual compression of the bogs and soils of the country, which has followed the introduction of the general system of canal-drainage. However this may be, the evidence supplied by borings and by the superficial strata exposed to view in some of the canals, renders it certain that Holland has experienced a degree of submergence in postglacial times which cannot be attributed to a mere lowering of surface consequent upon the consolidation of bogs and their associated deposits. Tetens, writing in 1778, tells us that from Schleswig to the mouth of the Scheldt peat occurs more or less deeply buried underneath recent marine accumulations.[2] These deeply buried peat-beds are known as *Dargschichten*, in East Friesland, where they occur at a depth of from 10 or 12 feet to as much as 40 feet and more below the present sea-level. They are frequently interbedded with marine clays, as in the following section from the Warfen :—[3]

Clay	10 to 14 feet.
"Knick," a hardened, ferruginous clay . .	2 ,, 3 ,,
Calcareous loam	15 ,, 18 ,,
Darg (peat)	6 ,, 15 ,,
Sand or loam	2 ,, 12 ,,
"Geest,"[4] (sand).	

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[1] S. von Waltershausen: *Natuurk. Verh. Holl. Maatsch. Wett. Haarlem*, Dl. xxiii. p. 337.

[2] *Reisen in die Marschländer an der Nordsee*, Bd. i. p. 172.

[3] For these details, see Arends: *Physische Geschichte*, Bd. i. pp. 84, 149, 231; the same author's *Ostfriesland und Jenver*, Bd. i. p. 22; and Dr. Grisebach's *Ueber die Bildung des Torfs in den Emsmooren*, p. 83, to which work I am under special obligations for references to these and other sources of information.

[4] This is the term applied in Westphalia and Holland to the sand and gravel

Similar appearances are shown in the following record of a boring put down near Emden:—

Alluvium (marine)	13 feet.
Darg (peat)	4 „
Soil-bed	1 „
Alluvium (marine)	1 „
Darg (peat)	2 „
Soil-bed	1 „
Alluvium (marine)	1 „
Darg (peat)	1 „
Alluvium (marine)	2 „
Darg (peat)	3 „

The *Darg*-peat in East Friesland varies, according to Professor Grisebach, from 1 to 15 feet—2 to 4 feet being a medium or average thickness. Near Brockdorf in Holstein, however, its thickness is as much as 20 feet.[1] It is generally of a yellowish-brown colour, and of a consistency between that of heather-peat and ordinary moss-peat. The plants of which it is composed betray its land-origin. Grisebach says it contains many stalks, one to two inches thick, of reeds and rushes similar to those which are common upon the margins of such rivers as the Rhine and the Maas, and he has no doubt that it has been formed in the same way as meadow-peat, which grows upon low marshy ground. Ehrenberg, he says, got microscopic marine organisms (*Polythalamiæ*) in the *Darg*, and the alluvia with which it is interbedded are clearly of marine origin, but the peat itself is composed wholly of land- and freshwater-plants. After a careful examination under the microscope, Grisebach did not succeed in detecting a single trace of any marine algæ. The mere occurrence of intercalations of marine alluvia does not therefore prove the marine origin of this bottom-peat, as some writers have supposed. The peat which occurs above the *Darg* and its associated marine beds attains a thickness in Holland and

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which form the "high and dry ground," and which have been proved to extend underneath the peat, blown sand, and recent marine clays of those countries, as at Rotterdam, Antwerp, and many other places. Carl Vogt: *Lehrbuch der Geologie und Petrefaktenkunde*, Bd. ii. p. 125.

[1] Kuss: *Naturbeschreibung der Herzogthümer Schleswig und Holstein*, p. 36.

West Friesland of 10 to 15 feet, and is covered in like manner with marine clay and silt, yet its bottom-layers are abundantly charged with stools and trunks of trees. The phenomena, as described by Arends and Grisebach, would appear thus to be closely paralleled by the peat-beds of the Lincolnshire Fens. In the interior of the Low Countries we find peat-bogs with buried trees,[1] which, as they are followed to the lower-lying tracts and the coast, are overlaid by recent marine deposits, while underneath this upper peat occurs, at a variable depth of from 10 to 40 feet, an older peat with intercalated marine silt and clay. Grisebach is of opinion that the *Darg*-peat, like the so-called forest-bogs, was formed upon the land, and that it gradually became covered with marine alluvium during continual encroachments by the sea. High-tide floods would cover it here and there with mud and silt, upon the surface of which, when the waters had retired, marshy vegetation would spring up anew until another high flood overspread the low coast-lands as before with a fresh deposit of silt, upon which the plants would again encroach until the next irruption ensued, and a third layer of silt was formed—the land of course slowly subsiding the while. All these changes were effected long before the dawn of history, and the marshes and peat which now overlie the *Darg* or bottom-peat were already in existence in the time of the Romans, as is rendered evident beyond dispute by the appearance of Roman structures resting upon the most recent alluvial deposits of the land.

Peat with the stools and roots of trees is well known to occur at and below the sea-level at many points on the Belgian coast and the French shores of the Channel. The peat of the Flemish coast, which occurs between high- and low-water mark, has been described by M. Debray,[2] and according to him it shows the following succession :—

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[1] In East Friesland these bogs contain trunks of oak and pine 50 to 60 feet long, and 2 to 3 feet thick. The trees lie from north-west to south-east, and are said to bear the marks of axes and fire.—S. von Waltershausen.

[2] *Bull. Soc. des Sciences de Lille*, t. xi. 1872 ; *Ann. Soc. Roy. des Sciences de Lille*, 1870-74, pp. 19, 84 ; *Bull. Soc. Géol. France*, Sér. 3. t. ii. p. 46.

	Mèt.
1. Fen or marshy deposit	0·20
2. Gray clay or sand, with sea-shells and brackish water bed above	0·83
3. Blue clay, more or less sandy, with sea-shells	0·82
4. Turf or peat	1·10
	2·95

Pottery of Gallo-Roman age is found upon the surface of the lowest bed of turf or peat, sometimes even at some little depth below that surface; and M. Debray is of opinion that the formation of the peat had been nearly or even entirely completed by the time the Romans occupied the country. From the discovery of coins and medals of Posthumus which lay upon the surface of the peat, it may be inferred that the beds above cannot date beyond the epoch at which that emperor lived. Now and again flint implements, probably of Neolithic age, occur in the turf, which has also yielded the remains of many animals, such as horse, ox, red-deer, roebuck, ram, dog or wolf, wild-boar, polecat, duck, buzzard, domestic fowl, balene-whale, cachalot, sturgeon, etc. When dry the peat shows many wing-cases of *Donaciæ* which have preserved their brilliant colours.

The famous peat-deposits of the Somme Valley extend out to sea, and belong approximately to the same date as those of the Flemish coast. This is proved by the fact that Gallo-Roman remains are confined to the surface and superficial part of the peat, while Neolithic relics occur in the deeper portions. The accumulation varies in thickness from a few feet up to ten yards and more, and has yielded remains of many trees, such as oak, alder, hazel, yew, fir, etc., together with numerous bones of quadrupeds, comprising amongst others the beaver and the bear (*Ursus arctos*).[1] The deep turbaries of Albert and Aveluy, which also occur in the Department of the Somme, have furnished, according to M. Debray, animal remains belonging to horse, red-deer, roebuck, ox, wild-boar, badger, beaver, rat, domestic fowl, duck, and man—the latter represented by a skull, and by implements and weapons of Neolithic types. In the valley of the Somme the break between the Palæolithic and the Neolithic deposits is very clearly shown. The excavation of the valley had been completed before any of the peat began to form; the great flooded rivers and inundations had disappeared, and the surface of the ground had assumed very much its present conformation long before the oaks and yews of the peat had commenced to flourish in the valley of the Somme.

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[1] *Antiquity of Man*, 4th ed., p. 154.

Submarine peat and trees have been noted at many points upon the coasts of Normandy, as at Villers in the Calvados, between the mouths of the Orne and the Seule, at Criquebeuf, near Vaches-Noires, near Cherbourg and La Hougue, and along all the west coast of Contentin. The same phenomena are continued upon the coast of Brittany, as at St. Malo, Dol, at Rodeven, near Plouescat, at Saint-Pierre-Quilbignon in the Bay of St. Anne, near Morlaix in the Bay of Fresnaye, and other places. Trunks of trees occupying the place of growth have likewise been observed under the level of the sea as far south as Arcachon (Gironde), and accumulations of vegetable *débris* and clay are prolonged under the sea-level at the mouth of the stream Mouligna near Biarritz.[1] No thorough examination appears to have been made of any of the submarine peat and trees of the districts just referred to, and we cannot therefore be certain whether or not they are of the same age as that of the Somme and the Flemish coast. Nor, so far as I know, have they disclosed a succession of beds like that which is furnished by the postglacial and recent deposits of Cornwall. Some antiquarians, indeed, maintain that the submarine trees that occur along the coast between St. Malo and Cape La Hougue are the relics of a broad belt of forest-land which was overwhelmed by the sea in the year 709, although the submergence was not completed till 860. There may possibly enough be some truth in these statements, but it is questionable if the submergence was so great as antiquarians suppose. I know that in Scotland the well-known occurrence of trees under peat has often suggested legends of ancient forest-lands having been dismantled in historic times, and even grave historians have pointed to the occurrence of the buried trees as proof that the land was everywhere covered with vast forests at the Roman period, although by far the larger portion of the forest-bogs of Scotland certainly dates back to a much greater antiquity.[1] Although, therefore, it may be quite true that there has been some recent loss of land in the maritime districts of Brittany, in the Channel Islands, and on the opposite coasts of Cornwall, there is yet no reason to believe that this has been so extensive as some antiquarians suppose. At all events, we shall probably not err in assigning the growth of the now submerged trees and peat of the Channel Islands and the adjacent French shores mainly to prehistoric times. They are in all probability merely a continuation of the similar phenomena in the Departments of Somme and Calais and in Flanders, and the forest-bogs of the inland districts of France and Northern Europe generally belong in great measure to the same distant period.

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[1] Delesse: *Lithologie des Mers de France*, etc., p. 437; Adouin and Milne Edwards: *Recherches pour servir à l'Histoire Naturelle du Littoral de la France*, etc., t. i. p. 193, *et seq.* See also Peacock: *Phys. and Hist. Evidences for Vast Sinkings of Land*, etc.

It is from those bogs that we derive the most interesting details of Postglacial history. Indeed, but for them we should know very little of the series of changes which took place in Central and Northern Europe after the close of the Glacial Period. There are no recent marine deposits like those of Scandinavia and the British area, which by means of their organic remains might throw light upon the question of postglacial climate in the inland districts of our continent. In those regions all the relics we are in search of must be looked for in fresh-water tufas, river- and lake-alluvia, and peat-bogs; and these last accumulations, as I have indicated, are by much the most important. They attain a great development in Holland, Denmark, Schleswig-Holstein, and Northern Germany, where, owing to the absence of coal, they are of the greatest value, and were even more so before the introduction of railways rendered the mineral fuels of other countries more available. Accordingly, we find that the peat has been carefully studied from early times by Scandinavian, Dutch, and German writers, so that the literature of the subject is voluminous. The older descriptive accounts, however, are taken up principally with the economic importance of the subject, with the extent of the bogs and the quantity available for fuel, with the chemical composition and relative quality of the different kinds of peat-earth and turf. There are few of those writers, however, who quite ignore the geological aspect of the question; and some of them, especially Degner, have discussed the origin of the peat and the buried trees which it so frequently encloses with great acumen and intelligence. But it is to the more recent essays of Steenstrup, Grisebach, Nathorst, Blytt, and others, that we are indebted for an account of those facts which point to former changes of climate. The earlier observers have generally attributed the formation of the bogs to the felling of the ancient forests by the Romans, but later investigations have shown that most of the bogs date back to a far higher antiquity, and owe their origin to the operation of natural causes. It is not my intention, however, to give a general account of the peat-bogs of Northern Europe, which would lead me far beyond the limits of the present inquiry, and I must therefore content myself by referring the reader to the various treatises mentioned in the note below.[1]

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[1] The various traditions and antiquarian evidence relating to the past condition of the coasts of the Channel Islands and the adjacent shores of France have been industriously compiled by Mr. R. A. Peacock, who refers to an ancient chart of that part of the French coast, said to be of date 1406, but copied from one much older, which shows Jersey connected with the mainland, and Guernsey of much larger size than now. Into the antiquarian evidence I cannot enter, but grave doubts as to the authenticity of the ancient chart will obtrude themselves. Jersey was certainly an island in 550, since it is mentioned in records as having been granted by a king of France to the Archbishop of Dol in Armorica about that date, and I fear that considerably stronger evidence than is yet forthcoming will be required to convince geologists that some 1300 or 1400 years ago a map existed, the main features of which correspond so surprisingly with the lines of soundings laid down upon the Admiralty's charts.

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[1] Among the better known and more interesting treatises are the following:—
Abildgaard: *Abhandlung vom Torf*, 1766 (translated from the Danish of 1762).
Blytt: *Essay on the Immigration of the Norwegian Flora during alternating Rainy and Dry Periods*, 1876, p. 37.

For my purpose it will be sufficient to give the results arrived at by Steenstrup from a study of the Danish peat, together with those obtained by Nathorst in Sweden, Denmark, and Germany, and by Blytt in Norway. I shall then refer shortly to the observations of Fliche in France, and of Martins and Heer in Switzerland.

The peat-bogs of Northern Europe repose generally upon deposits of glacial and fluvio-glacial origin—boulder-clay, sand and gravel, and löss. These deposits may be said to cloak with an almost continuous covering the vast low-lying regions that extend along the borders of the North Sea and the Baltic, sometimes forming wide plains with only a few gentle undulations, at other times rising into low hills and hummocks. They preserve a dreary monotony of outline over some thousands of square miles. In Holland, Denmark, and Northern Germany, enormous tracts of country are covered with heath and bog—which, although they are being continually encroached upon by agriculturists, still form one of the most extensive areas of uncultivated ground in Europe. But the evidence supplied by the bogs shows that the land has not always been so bare. The great pine forests which still exist in many places in the mari-

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Dau : *Neues Handbuch über den Torf*, 1823.
,, *Ueber die Torfmoore Seelands*, 1829.
Dazel : *Ueber Torf, dessen Entstehung, Gewinnung, und Nutzung*, 1795.
Degner : *Dissertatio Physica de Turfis*, etc., 1729.
De Luc : *Lettres physiques et morales sur l'histoire de la terre et l'homme*, 1779 ; contains accounts of peat and buried trees of North Germany, Holland, etc.
Eiseln : *Handbuch zur Kenntniss des Torfwesens*, 1802.
Grisebach : *Ueber die Bildung des Torfs in den Emsmooren*, 1846.
Lesquereux : *Bull. Soc. Sci. Nat. Neuchâtel*, 1847, vol. i. p. 472.
Lindeberg and Olbers : *Om Bohuslens Torfmossar.*
Olafsen : *Dennemarks Brandselvasen*, 1811.
Riem : *Abhandlung vom gesammten Torfwesen*, 1794.
Schinz-Gessner : *Der Torf, seine Entstehung, Natur, und Benutzung*, etc., 1857.
Senft : *Die Humus, Marsch-, Torf-, und Limonit-Bildungen*, etc., 1862.
Steenstrup : "Geognostisk-geologiske Undersögelse af Skovmoserne Vidnesdam og Lillemose i det nordlige Sjelland," *K. Dansk. Vidensk.-Selbsk. Afh.*, 1841 ; *Report of the Smithsonian Institution*, 1861, p. 304 ; *Bull. Congrès Intern. d'Archéol. Préh.*, 1869 ; *Lecture on the Antiquity of Man* (by Prof. T. R. Jones, 1877, p. 10).
Wiegmann ; *Ueber die Entstehung, Bildung, und das Wesen des Torfes*, 1837.

time districts are only feeble representatives of the arborescent vegetation which in former days appears to have covered the major portion of Northern Europe. Even within historical times the forests are known to have been more extensive than they are now, but the true Age of Forests goes back to an archæological period.

There are three principal kinds of peat-bogs described by continental writers, which correspond to our meadow-bog, hill-bog, and bog with buried trees or forest-bog.[1] These different kinds of bog pass into each other, so that a hard-and-fast line cannot always be drawn between them. From our present point of view the forest-bogs are the most important, and not the least interesting are those of Denmark, described by Professor Steenstrup. They are found in basins of inconsiderable size, which, however, are deep in proportion to their width. Some of the smaller bogs are not much more than 30 or 40 yards across. The pot-like depressions which have been specially examined by Steenstrup occur in the great drift or glacial deposits that cover so wide an area in Denmark, and appear to have existed at one time as pools and lakelets. This is shown by the appearance at the bottom of the bogs of alluvial clay and marl, with remains of freshwater organisms and land-plants. From this clay Nathorst, in company with Steenstrup, extracted the relics of an arctic flora, consisting of polar willow (*Salix polaris*), herbaceous willow (*S. herbacea*), netted-leaved willow (*S. reticulata*), mountain-avens (*Dryas octopetala*), and dwarf birch (*Betula nana*). Immediately above the clay, in the Lillemose and other bogs of the same character, comes a layer of water-plants (*Potamogeton, Chara, Myriophyllum*), with leaves of the aspen (*Populus tremula*), and this in turn is covered with a stratum of peat composed of *Hypnum cordifolium*, and containing trunks of Scots fir (*Pinus sylvestris*). These trees had evidently grown upon the margin and steep inner slopes of the basin. Above them succeed trunks of oak (*Quercus sessiliflora*), which are likewise buried in peat, and have evidently fallen in from the sides of the basin, in the same manner as the Scots firs. The uppermost portion of the peat is marked by the presence of the alder. Such is the general succession met with along the margin or outer zone of the basin. In the central region remains of trees are not so abundant. The bottom-portions are composed exclusively of moss-peat. Farther up, however, roots and trunks of stunted pines make their appearance, indicating in some swamps as many as two or even three distinct layers of roots and trunks of such pines. Still higher up the pine disappears and is replaced by white birches, and afterwards by alders and hazels. The pines and oaks of the outer woody zone were noble trees, the former often attaining a thickness of three feet, and being correspondingly tall. Many of the oaks are even thicker, measuring often four feet in diameter. The close juxtaposition of the stools and the straightness of the trunks show that the forest-growth was dense. These facts teach us that before the peat had commenced to accumulate Denmark was bare and devoid of forests. Its surface was dappled with lakelets and pools, and covered with a scanty arctic flora, the character of which betokens a climate like that of Lapland and the far north. By and by, however, the climate became less severe, and aspens and pines gradually overspread the land, the thick bark of the latter betokening colder winters than Denmark now experiences. The trees appear to have crowded everywhere, growing densely along the margins of pools and lakelets, which water-plants and mosses were converting into marshes. From time to time, borne down by wind, or age, or snow, the trees fell into the marshy basins, pools, and swamps, and were there by degrees buried in the accumulating peaty matter. A gradual change of climate is evinced by the drying-up of many of the basins, and the appearance of pines which flourished upon the surface of the bogs themselves, and the change is still more strongly indicated by the advent of the oak, which eventually supplanted the pine, and formed the principal tree in the Danish forests. Lastly, the great oaks, too, disappear from the margin of the *Skovmoser*, or peat-bogs, and a thick growth of sphagnum-peat gathers over their prostrate trunks, forming the uppermost peat-layer, upon the surface of which grew here and there the warty birch (*Betula verrucosa*) and the alder (*Alnus glutinosa*). The pine, I need hardly say, is no longer a native of Denmark, nor is there any historical or legendary evidence of its ever having been so. The oak which replaced the pine is now much less abundant, and seems on the decline itself, the ground being occupied by the beech as the principal tree, no trace of which has yet been met with in any of the Danish bogs.

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[1] The Danish terms are *Kjærmose* or *Engmose*, *Lyngmose*, *Svampmose* or *Hoermose*, and *Skovmose*, which answer to the German *Wiesenmoor*, *Haidenmoor* or *Hochmoor*, and *Holzmoor* or *Waldmoor*. Many varieties of peat are described by German writers, such as *Sumpfmoor*, *Sumpftorf*, or *Moostorf* (Sphagnum peat), *Haidetorf* or *Erikentorf* (heather-peat), *Marschtorf* (marsh-turf), etc.

Neolithic implements have frequently been found associated with the buried pines of the forest-bogs, but they occur also in connection with the oaks. It was during the ascendency of this tree in the forests that the knowledge of bronze seems to have been introduced to Denmark. How long a period elapsed before iron came into general use we cannot tell. All we know is that the Bronze Age endured for a very considerable time. But whether or not it is the case, as some archæologists have supposed, that the beginning of the Iron Age may have been synchronous with the introduction of the beech into Denmark, there is no evidence to show. Unquestionably, however, that Age belongs essentially to the epoch of the latter tree. It is a mistake, however, to classify the Neolithic, Bronze, and Iron Ages of Denmark as corresponding, more or less precisely, to the epochs of pine, oak, and beech respectively. Stone implements appear to have been in exclusive use well on into the oak epoch, and for aught we know to the contrary the beautiful beech-forests of Denmark may date back to the Age of Bronze.

The peat-bogs of Norway abound in buried timber; and in many cases the trees occur on two horizons. The lower forest-layer consists principally of oak, hazel, ash, and other deciduous trees, with stools and roots in place, and now and then it is underlaid by several feet of peat. Above this lower buried forest comes a variable thickness of peat, from two or three up to six feet or more. To this bed succeeds a second forest-layer composed of the stools and trunks of Scots firs and birches, which in their turn are buried under overlying peat, which may be as thick as the peat below. Mr. Axel Blytt says there are perhaps even more than two buried forest-layers, but certainly two would seem to be the common number. It is worthy of note that in the Norwegian bogs the oak-forests underlie the pine-forests, and the same is the case in the peat of Sweden, according to Lindeberg and Olbers. Blytt remarks that the bogs of Norway prove that the bare sea-coast, where now scarcely a tree grows, was once clothed with forests all the way from Lister to Nordvaranger, in East Finmark. Not only, he says, has the Scots fir formerly grown still farther to the north, but it also at one time reached a greater elevation in the mountains, for its remains occur in bogs above the limits attained by the tree at present. Sometimes, indeed, it grew in places where not even the birch is now to be found. According to Blytt, the succession of changes to which the peat-bogs bear witness is as follows:—1st, A wet period, when bog-mosses formed the bottom-peat, which in some places underlies the older of the two forest-beds. 2d, A genial period, when all the low grounds were covered with a thick growth of oak, hazel, ash, and other trees, and when the horizontal and vertical range of the forests was much greater than it is now. 3d, A wet, ungenial period, during which bog-mosses and other moisture-loving plants increased abundantly, while the trees at the same time, ceasing to flourish, fell, and sooner or later were buried in the accumulating peat. 4th, A return of drier conditions, when the bogs no longer increased so generally, but dried up and allowed trees to grow upon their surface. The forests which at this time overspread the country were formed of great coniferous trees,[1] that enjoyed a much more extensive horizontal and vertical range than the same trees do now. 5th, Another wet period succeeded, when the forests decayed as before and were gradually overwhelmed by a renewed growth of the bogs. 6th, The present appearance of the bogs shows that the conditions have become less humid.

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[1] Blytt mentions stumps that measured 12 feet in circumference. In one stump with a girth of 6 feet he counted 200 rings of growth.

Neolithic implements have been met with from time to time in the Scandinavian bogs, generally not deeper down than two feet or so, from which Blytt infers that in those bogs not more than two feet of peat has formed within historical times. The rate of growth of peat, like that of stalagmite, has been a much disputed question—some holding that it forms very rapidly, others that its growth is extremely slow. The fact is that the growth is regulated by the supply of moisture and by climatic conditions, and the remarks made in a former page with reference to the formation of stalagmites hold equally true of peat. Not only does peat form at different rates in different regions, but the same is often the case even in one and the same bog—the bog being dry in some places, where it actually wastes and crumbles away, while in other portions the mosses flourish more or less luxuriantly. But even if it were true that peat accumulated now at an equable rate throughout Northern Europe, still that would not help us much in our endeavour to ascertain the length of time required for the formation of our bogs. The structure of the peat indicates the former prevalence of greater humidity, during which moisture-loving plants flourished more abundantly than under present conditions, and other things being equal, the bogs generally must have increased more rapidly then than they do now. Nothing, indeed, can be more misleading than to take the known rate at which peat has accumulated in some particular place as a standard of measurement by which to judge of the antiquity of all other bogs. Steenstrup has shown that peat in his country increases at so very slow a rate that it is of no account in an economical point of view, and Blytt is of the same opinion in regard to the peat of Norway. From what he observed in Jæderen, he concluded that "when people cut peat in bogs which had been cut by their fathers or grandfathers, it was obviously not peat formed in recent times, but the old black peat, the cutting of which was formerly prevented by the influx of water." I have often made the same observation in Scotland. The country people would be very well pleased if peat available for fuel would form in places which were stripped bare by their fathers and grandfathers. But they know that with every year that passes fuel must be sought for farther and farther afield, and I have frequently seen it brought from distances of several miles to hamlets and villages in the immediate neighbourhood of which it used to be dug 50, 100, or 150 years ago, but where there is not the slightest evidence of any appreciable peat-growth having taken place since the bogs were exhausted. If the present rate of growth in such regions were to be taken as a standard of comparison, what age should we assign to bogs exceeding 20 or 30 feet in depth? It would be absurd, however, to suppose that peat has never grown more rapidly in former times; and the occurrence of Roman and Scoto-Saxon relics embedded in the bogs is proof that even in the historical period the rate of growth has exceeded that which we now observe in Scotland. But it is not always safe to infer that all the peat that overlies a Roman sword or axe has been formed since the Roman occupation. Metallic objects might easily sink in time through a considerable depth of soft peat, and I know that a geological hammer of no great antiquity might be disinterred to-morrow from a quaking bog in South Ayrshire, probably at a depth of several feet from the surface. Peat is not now increasing generally in Scotland—the rate of decay is in excess of growth in most bogs which I have visited, and Blytt has made the same observation in Norway. Here and there, however, when the supply of moisture is abundant, the bog-mosses thrive well enough, and are doubtless adding to the thickness of the peat. But I can give no measurements to show the average rate of growth in such places. Mr. Kinahan states that in certain Irish bogs "each year's growth is represented by a layer or lamina, and these laminæ in the *white turf* (uppermost portion of a bog) are about, on an average, one hundred to the foot; in *brown turf* (lower portion) two hundred to three hundred; and in *black turf* (bottom portion) from six hundred to eight hundred; but their numbers are different in the different bogs, as one grows more rapidly than another." The undrained bogs of Ireland would thus appear to be still increasing, which is not the case generally in Scotland, although in the rainier districts the evidences of arrested growth and of decay are less conspicuous than elsewhere. The sum of the matter is that we have no exact data by which to compute the time required for the formation of a given thickness of peat, the rate of growth being extremely variable, not only in different regions, but in one and the same bog. Moreover, even if we could prove the present existence of an uniform rate, the fact that the climate has undergone considerable changes would vitiate our results, and render our standard of measurement of no avail. Nevertheless, in very many cases, it is quite evident that the bogs are of great antiquity, and that it has often taken several thousands of years to form a thickness of twenty, or even of ten, feet. Thus Steenstrup thinks it may have required at least four thousand years for the growth of the Danish forest-bogs, and perhaps this, he says, may be only a third or fourth of the time actually involved.

I have mentioned the fact that an arctic flora has been found at the base of the Danish forest-bogs. Mr. Nathorst has detected the same flora in over twenty localities in southern Sweden.[1] The most southerly place from which he has recorded this interesting flora is near Greflunda and Bästekille, on the borders of the parishes of Mellby and Hvitaby, where he obtained the arctic willow in freshwater clays under a bed of peat, at a height of 400 feet above the sea. The other localities ranged from 150 to 500 feet above the same level. The general succession of the deposits met with was as follows :—

Peat	3½ to 4 feet.
Silt	½ to 1½ „
Sand	0 to 1 „
Silt with shells . .	1½ to 4½ „
Sand	0 to 1 „
Sandy clay . . .	2½ feet.
Sandy clay with mosses .	1½ „

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[1] *Geol. För. i Stockholm Förh.*, 1877, Bd. iii. No. 10.

The mosses in the sandy clay at the bottom have been determined by S. A. Tullberg, and are *Hypnum giganteum*, Sch., and *H. fluitans*, both of which are still found throughout Sweden from Scania to Finmark, and according to Bergren they extend to Bear Island, Spitzbergen, and Greenland, and are especially common in the last-named region. Associated with these mosses Nathorst found leaves of *Salix polaris*, *S. reticulata*, and *Dryas octopetala*, the Arctic willow being very abundantly represented. The shells belonged to freshwater molluscs—*Pisidia*, and a *Limnæa* nearly allied to or identical with *L. limosa*. In the shelly silt the Arctic willow was not so plentiful, the netted-leaved willow taking its place. Other plants met with were a *Myriophyllum*, *Salix herbacea ?* and *Betula nana*. In the upper part of the shelly silt, or between that and the overlying sand and silt, remains of the reindeer have been found. The peat is composed in large measure of water-mosses. Lowest down in it occurs *Hypnum giganteum*, Sch., and higher up *H. scorpioides*. In the uppermost portion of the peat these are replaced by a *Hypnum* which has not yet been specifically determined, but is probably *H. cuspidatum*. With it is associated *Paludella squarrosa*. These mosses occur throughout all Scandinavia, while the *Paludella* has a decidedly northern range, being very common in Spitzbergen, Bear Island, and Greenland. The range of *H. giganteum* has already been mentioned, and *H. scorpioides* is, like it, abundant in high Arctic regions.

Mr. Nathorst has traced the same Arctic flora across Germany into Switzerland.[1] Near the railway station of Oerzenhofs between Neu Brandenburg (in Mecklenburg) and Strassburg (in the Prussian province of Brandenburg), he observed freshwater deposits under the small peat-bogs which occur in that neighbourhood. These contained shells, together with *Myriophyllum* and *Potamogeton*, and remains of *Betula nana* and *B. alba*. He mentions also the occurrence of northern shells in postglacial freshwater clay at Angermünde on the railway between Stettin and Berlin. The species were determined by G. O. Sars, and are *Limnæa limosa, Pisidium,* probably *pulchellum,* and *Cytheridea torosa.* At Kolbermoor, in the south-east of Bavaria, Nathorst found *Betula nana, B. alba, Myrtillus uliginosa,* and *Oxycoccus palustris,* at a depth of eight feet from the surface in a peat-bog, the dwarf-birch being so very abundant that its remains form a regular layer or bed. Higher up in the peat (composed principally of *Sphagnum, Eriophorum,* etc.) appeared leaves of *Andromeda polifolia* (moorwort), a small shrub common in the northern countries of our continent. At the time the dwarf birch was growing so plentifully on the Bavarian bogs, the conditions must have been such as one now meets with on the peat-bogs of northern Sweden and Norway. It is interesting to find, Nathorst remarks, that species which formerly grew abundantly on the surface of the peat have now retreated to the tops of some of the highest mountains in Bavaria. Besides the plants named by Nathorst as occurring in the Bavarian peat, Prof. Zittel mentions also *Salix herbacea* and *Dryas octopetala.*[1]

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[1] *Öfvers. af K. Vet.-Akad. Förh.*, 1873, No. 6.

Mention has already been made of Nathorst's discovery of an arctic-alpine flora in Switzerland,[2] and I shall now refer to only another example of the occurrence in peat of plants that indicate colder conditions than the present, an example which is sufficiently suggestive. In the environs of Troyes (Champagne) the small affluents of the Seine flow in valleys, the bottoms of which are here and there clothed with turbaries which have been examined and described by M. Fliche.[3] They have yielded an abundant suite of animal and vegetable remains, together with human relics. The latter are plentiful and consist of charcoal, potsherds, broken and worked bones, flint implements, polished and well chipped, and others showing much ruder workmanship, fragments of sandstone, and various objects in bronze and iron. The stone implements were found in the lower and deeper part of the turbaries, while the objects of metal occurred towards the upper surface. The fauna included badger, otter, dog, beaver, wild-boar (*Sus scrofa*, L., *ferus* and *palustris*, Rütim.), domestic pig, horse, red-deer, paseng, sheep, ox (*Bos taurus*), urus. The birds are represented by a swan (*Cygnus musicus*, Temm.); amphibians, by the toad; and insects by *Geotrupes vernalis*, L. and G., *G. putridarius*, Erichs., *Donacia crassipes*, Fabr., etc. Land- and freshwater-shells of living forms were also abundant. The trees included *Rhamnus catharticus*, L. (purging buckthorn), elm, walnut, oak (probably *Quercus pedunculata*), hazel, birch (probably *Betula pubescens*, Ehrh.), alder, willow (probably *Salix fragilis*, L.), yew, juniper, spruce fir, and Scots fir. Other plants are *Menyanthes trifoliata* (marsh trefoil), *Polystichum spinulosum*, Koch.; *Equisetum arvense*, L., and *E. limosum; Hypnum aduncum*, Hedw., and its variety *polycarpon*, Schimp.; *H. fluitans*, Dill. var., and var. *submersum*, Schimp.; *H. falcatum; H. pratense; H. giganteum*, Schimp.; *H. scorpioides*, Dill., etc.

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[1] "Ueber Gletscher-Erscheinungen in der bayerischen Hochebene," *Sitz. der k.-bay. Akad. der Wiss. zu München,* 1874.

[2] See *ante,* p. 55.

[3] *Comptes Rendus des l'Acad. des Sciences,* t. lxxxii. p. 979.

During the deposition of the clay which underlies the peat, the country was covered, says M. Fliche, with spruce firs, pines, willows, birches, and alders. But when the turbaries began to accumulate the spruce firs had disappeared, although the pine still flourished and continued to occupy the ground for a long time, its remains occurring all through the forest-bed which is buried in the peat. With the pine are associated yew and juniper, but these are not so common, while by and by the pine disappears and oak and elm become abundant. The old forest thus presented an aspect which one no longer encounters in the woodlands of Champagne; to meet with a similar assemblage we must advance to the north-east as far as Haguenau or Bitche. The pine and the yew have vanished, and the juniper remains the only representative in Champagne of the old conifers, while the oak is now more plentiful. The mosses confirm the results furnished by a study of the trees. They are most characteristic of the deeper part of the peat, and appear even in the underlying clay. They all pertain to species or varieties which demand a very wet habitat and cold climate, and some are most abundant nowadays in Arctic regions. Many have abandoned the low grounds of France altogether, while some, such as *Hypnum scorpioides*, still linger on.

Peat-bogs, as I have said, attain their greatest development in Northern Europe, but they are met with also not only in Northern France, the Vosges, the Black Forest, Bavaria, and Switzerland, but likewise in the mountains of Auvergne and the Cevennes, in the Pyrenees, Northern Italy, and many other elevated regions in the more southern parts of the Continent. The vegetation of which they are composed has certain elements in common, many of the plants being characteristic of Scandinavia and the north. Professor Ch. Martins has discussed the origin of that peat-flora in a very interesting manner, and has shown conclusively that it owes its wide dissemination to the cold of the Glacial Period,[1] and Professor Heer has illustrated the subject abundantly in his account of the present distribution of the arctic-alpine plants of Switzerland.[2] The peat-bogs are, as it were, asylums to which the northern plants, once common to the low grounds of Europe, retreated in postglacial times, driven out by the returning hosts of the temperate flora. And they now flourish only in places which by reason of their altitude, and sometimes simply on account of their humidity and other unfavourable conditions, are not sought after by temperate species. More recently, Professor Engler has reviewed the whole question of the migrations of the various European floras in a highly suggestive manner, and has shown that the glacial or arctic element in the peat-flora is more marked than might at first sight appear. Indeed he is of opinion that the formation of the peat-bogs at the northern foot of the Alps began during the Glacial Period.[3]

Of the other postglacial and recent deposits—the fluviatile and lacustrine alluvia, shell-marl, calcareous tufa, etc., it is not necessary to speak. They may be studied broadcast over the Continent. It is enough to say that French, German, and

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[1] *Mem. de l'Acad. des Sciences et Lettres de Montpellier*, t. viii. p. 1.

[2] *Die Urwelt der Schweiz*, 2te Auflage, p. 582.

[3] *Versuch einer Entwicklungsgeschichte der Pflanzenwelt*, etc., I. Theil, p. 168.

Italian geologists distinguish clearly the postglacial alluvia from the older river-deposits of Pleistocene age. The more recent deposits invariably occupy the bottoms of the valleys, while the older Pleistocene loams and gravels frequently rise in terraces at higher levels, which often present cliffs or bluffs against which the modern alluvia abut. These appearances are well shown in such valleys as those of the Seine, the Rhine, the Weser, the Danube, the Po, and the Rhone.

Lists of the fauna have already been given. Speaking generally, the postglacial fauna of the Continent is the same as that which is represented in the postglacial and recent deposits of Britain. There are some points, however, upon which we are yet imperfectly informed: and one of the most important, I venture to think, is the range northward of some of the temperate species. How far north did the red-deer and its associates extend? Professor Grewingk records it from the postglacial deposits of Kurland, in which its horns are not uncommon. He says there is neither historical nor traditional evidence of its ever having been a native of that province, where its occurrence, he is of opinion, betokens a former milder climate.[1] It would be extremely interesting to ascertain whether remains of the same animal, and others of its congeners, occur in postglacial deposits still farther north in Russia and Sweden.

The oldest relics which have yet been found in any accumulations of postglacial age belong to the Neolithic era. Not a trace of Palæolithic man has hitherto been forthcoming. The lowest beds of peat contain either no human implements or only those of the Neolithic age. Higher up than these occur relics pertaining to the Bronze Epoch and more recent times.

Before passing on to review the evidence which has now been adduced, I must mention some remarkable facts connected with the postglacial beds of Spitzbergen, which it will be seen in the sequel have a strong bearing upon the problem of postglacial climate. The beds referred to consist of banks of shelly sand and gravel, but in many places they are made up almost exclusively of shells, and principally of those of the common mussel. They were first noticed during the Swedish Expedition of 1861 by Malmgren and Torell, who detected the mussel-beds in Hinlopen Strait, on the north coast of Spitzbergen, and by Blomstrand, who found them at Advent Bay, in Ice Sound; and this latter locality was minutely examined by Nordenskiöld and Malmgren in 1868. The beds run up to a height of 200 feet above the sea, and in some places are overlaid by a thickness of eight and twelve feet of peat. They have yielded nine species of molluscs, of which two, *Cyprina islandica* and *Littorina litorea*, no longer live in the Spitzbergen seas. The former of these is found living off the coast of Greenland, but the latter does not now come so far north. The common mussel is also a native of the Greenland waters, but it seems doubtful if it is at present living in the seas of Spitzbergen. Agardh, indeed, found a few adhering to some algæ on the coast of the island, but it has never again been met with by the Swedish naturalists, although carefully sought for. Even although a few individuals should still denizen these icy waters, yet the contrast between the present rarity of the species and its former great abundance is sufficiently striking. All the other shells met with in the mussel-beds are common arctic species living in the neighbouring seas. Associated with them are considerable quantities of algæ and other plants, amongst which *Fucus canaliculatus* is common, although it no longer occurs so far north. Heer mentions also the occurrence of *Dryas integrifolia*, *Betula nana*, and *Salix retusa*, but I am assured by Mr. Nathorst, who has made a special study of the arctic flora, and who himself has visited Spitzbergen, that the plants referred to by Heer are a form of *Dryas octopetala* and *Salix polaris*.

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[1] *Dorpater Archiv für Naturkunde*, Ser. i. Bd. viii. pp. 580, 588, 621. Remains of urus are said by Grewingk to occur sometimes along with those of red-deer. I am indebted to my obliging correspondent, Dr. Penck of the Geological Survey of Saxony, for calling my attention to these interesting notices.

Of course there is not the slightest doubt that these deposits are of postglacial age. The Spitzbergen fiords during the Glacial Period were filled with glacier-ice, which covered all the low grounds, and the postglacial beds repose upon ice-worn surfaces. Mr. Nathorst informed me that during his visit in 1860 he observed at Dickson's Bay a shell-bank resting upon a striated rock-surface, the striæ running parallel to the direction of the fiord.[1]

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[1] See Professor Heer's paper: *K. Svenska Vet.-Akad. Handlingar*, Bd. viii. No. 7, p. 80; and Professor Nordenskiöld's "Spitzbergens Geologi," *op. cit.*, Bd. vi., No. 7, p. 34. An English translation of this last-mentioned paper (*Sketch of Geology of Spitzbergen*, Stockholm) was published in 1867.

CHAPTER XXI.

CLIMATIC AND GEOGRAPHICAL CONDITIONS OF POSTGLACIAL AND RECENT PERIODS—SUMMARY.

Genial conditions in Southern Scandinavia—Mediterranean molluscs in Northern Seas—Southern forms in Gulf of St. Lawrence—Condition of Northern Sea in latest glacial epoch—Immigration of southern species in postglacial times—Migration of arctic flora in late glacial and early postglacial times—Edward Forbes on origin of British fauna and flora—Contrasts between Britain and Ireland—Large postglacial lake occupying bed of Irish Sea—Ireland derived its fauna and flora in part from Scotland—Genial climatic conditions—Former greater range of forests—Trees in peat of Færöe Islands and Norway—Peat with pine on shores of Wellington Channel—Origin of floras of Færöe Islands, Iceland, and Greenland—Former connection of those regions with Europe in postglacial times—Traces of former genial conditions in Kurland—Gradual disappearance of genial climate and submergence of land in north and north-west—Formation of 50-feet beach of Scotland—Local glaciers and swollen rivers—Cold and humid conditions, and increase of peat-bogs—Retreat of sea and amelioration of climate—Second great forest-growth—Second peat-forming period—The Present—Southern Europe in postglacial times—Date of advent of later Prehistoric races.

Having passed in review the evidence supplied by the Postglacial and Recent deposits, I shall now endeavour to point out its general bearing upon the question of climatic and geographical changes. In common with other geologists, I have hitherto maintained that we have no evidence in these deposits for any great oscillations of climate—no mutations at all comparable in magnitude with those which took place during the preceding Glacial or Pleistocene Period. My belief has been, that with minor fluctuations, such as might be caused by changes in the distribution of land and sea, the climate of our islands has passed gradually from an arctic to a temperate condition, and is now milder than it has ever been since the close of glacial times. I have come to think, however, that this is too broad a statement, and now incline to the opinion that the climate of the postglacial period, although most probably never so warm as that of the last interglacial epoch, was yet for some time marked by a more genial temperature than we now enjoy, and that this milder epoch was followed by what appears to have been a relapse to colder conditions than the present. I believe, further, that the geographical changes which took place in our own and more northern latitudes during postglacial times were on a far larger scale than most geologists perhaps are aware. This belief has been forced upon me not only by the geological evidence, but also by various considerations connected with the present distribution of plants in Iceland and Greenland. Notwithstanding all that has been written upon that interesting subject, there are still many points which want clearing up. Whence, and at what period, did Greenland, Iceland, and the Færöe Islands obtain their flora, is a question which has often been asked, but the answers given by eminent botanists have never quite satisfied all geological scruples. Although the subject is beset with difficulties and the evidence is not so abundant as one might well wish, I shall yet venture to say something about it. But, before doing so, it will be well to summarise the main features of the evidence supplied by the postglacial deposits.

At the beginning of postglacial times the southern region of Scandinavia was submerged for some 400 or 500 feet, and a large part of the Cimbric peninsula was also under water, so that the North Sea communicated with the Baltic across what is now Holstein. The British area, however, would appear to have been not less extensive than it is at present. Indeed, there is reason to believe that England had some direct connection with the Continent. The climate was still ungenial, but was gradually becoming less so. This is shown particularly by the character of the shells in the postglacial beds of

Norway and Sweden. Many of the arctic forms which occur in the older glacial clays are now wanting, while certain types of a southern facies begin to appear. As the land emerged the latter became more numerous, while at the same time the boreal and arctic forms retreated. It is remarkable that the southern molluscs were not only individually abundant, but their shells were larger and better developed than those of their descendants that still linger in greatly diminished numbers in the adjacent seas. Evidently the conditions under which they now live are less favourable than those that were experienced in postglacial times. Certain molluscs which were formerly plentiful upon the south coast of Scandinavia no longer occur there, but have retired to the more genial waters of the west coast. The postglacial shell-beds of Spitzbergen tell the same tale. The common mussel, at one time abundant in the fiords of that region, has apparently become extinct, and *Cyprina islandica* and *Littorina litorea*, which are associated in the Spitzbergen deposits with the mussel, have likewise disappeared from those inhospitable shores. Again, Dr. Rink mentions that a number of shells which were obtained by him from the clay-beds of Sarpiursak in Greenland were examined by O. A. L. Mörch, who found that they belonged partly to species still existing on the coasts of North Greenland and partly to more southern forms. Nor are we without similar indications in the marine postglacial beds of Scotland of a formerly more genial climate. Mr. Crosskey has drawn special attention to the so-called "*Pecten-maximus* bed" of the Clyde, which contains shells (*Psammobia ferroënsis* and *Tellina incarnata*), of larger size and in greater numbers than they at present occur living in the neighbouring sea.

The recent dredging expeditions which have been sent out from our own and other countries have moreover familiarised us with the fact that Mediterranean forms are now and again encountered in our northern seas, where they look strangely out of place. Thus Sir Wyville Thomson mentions that in 110 fathoms, about 40 miles off Valentia, the dredge brought up a number of northern species, such as *Neæra rostrata*, Spr.; *Verticordia abyssicola*, Jeff.; *Dentalium abyssorum*, Sars; *Buccinum humphreysianum*, Bennet; and *Pleurotoma carinatum*, Bivona, commingled with which were Mediterranean forms, which imparted somewhat of a southern character to the assemblage. Among these were *Ostrea cochlear*, Poli; *Aporrhaïs serresianus*, Mich.; *Murex lamellosus*, Cristof. and Jan.; and *Trochus granulatus*, Born.[1] Similar noteworthy "finds" have been recorded by Gwyn Jeffreys and others off the coasts of the Shetlands and the Outer Hebrides, and Mörch mentions that several genera of molluscs, which indicate a southern climate, are still found on the west coast of Iceland, such as *Actæon, Trochus, Patina, Nassa, Mactra* (*elliptica*), none of which is arctic. When we cross the Atlantic to the Gulf of St. Lawrence we encounter the same remarkable phenomenon. Professor Verrill has shown that there are genuine colonies of southern species in that gulf and on the coast of Nova Scotia, which are completely isolated from their co-species of the southern coast of New England, and surrounded on all sides by more northern forms.[2] And he tells us further, that at an earlier period these colonies were much more extensive. The shells of the round clam or "quahog" (*Venus mercenaria*) are abundant in the mud in places where no living ones could be found, and they likewise occur in great quantities in certain old Indian shell-heaps on many of the islands in Casco Bay, upon the coasts of which they do not now live. "That at a more remote period," says Verrill, "the marine climate of this region was still warmer, and the southern species were more abundant than during the period when the Indian shell-heaps were formed, is shown by the occurrence of great beds of oyster-shells a few feet beneath the mud in Portland harbour, where they are associated with quahogs and several other southern species, among which are *Callista convexa, Turbonilla interrupta*, and *Pecten irradians*. The last is not known to live at present north of Cape Ann, on the New England coast;" *Callista convexa* occurs sparingly in shallow sheltered localities in Casco Bay; "but the oysters (*Ostrea virginiana*) and 'scollops' (*Peeten irradians*) had apparently become extinct in the vicinity of Portland Harbour before the period of the Indian shell-heaps, for neither of these species occurs in the heaps on the adjacent islands, while the quahogs lingered on until that time, but have subsequently died out everywhere in this region, except at Quahog Bay." The position of the beds of oyster-shells, pectens, etc., shows that "no important change in the relative level of the land and water can have occurred in that region since they were formed." Professor Verrill says that he can explain the presence of the southern species in no other way than by supposing "that they are survivors from a time when the marine climate of the whole coast, from Cape Cod to Nova Scotia and the Bay of Fundy, was warmer than at present, and these species had a continuous range from Southern New England to the Gulf of Saint Lawrence."

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[1] *The Depths of the Sea*, p. 86.

[2] *Amer. Journ. of Science and Art*, Third Series, vol. vii. p. 134.

All these facts plainly show that the temperature of our northern seas has been exceptionally high at some recent period. In no other way can we account for the northern immigration of the southern species. These species tell of a time when the Gulf Stream carried into the North Atlantic a much greater body of heated water than now reaches such high latitudes. At one time I was inclined to assign that latest immigration of southern forms to the last interglacial epoch, and therefore looked upon the isolated colonies and individual species in our postglacial deposits and present seas as the few survivors who were able to outlive the rigour of the latest glacial epoch. But when we come to consider the nature of the conditions which obtained during that latest phase of the Ice Age, it seems hardly possible that any southern species whatsoever could have survived them. Few geologists, save those who have specially worked at the subject, have realised the extent of the glaciation that took place toward the close of the Glacial Period. So far as Scotland and Scandinavia are concerned, the ice-sheet which then covered them seems to have been hardly, if at all, less thick than that which mantled them at the very climax of glacial cold, when the European ice had its greatest extension. Not only were the Scandinavian and Scottish ice-sheets coalescent, but they overflowed the Orkney and Shetland Islands, and the Outer Hebrides were buried in ice to as great a depth as they seem to have been at any previous stage of the Glacial Period. How far west the *mer de glace* extended seawards can, of course, only be conjectured, but it is most probable that it reached, at least, to what is now the 100-fathom line. Mr. Helland and I found that the Færöe Islands had been in like manner enveloped in glacier-ice. They supported an ice-sheet of their own, the upper surface of which rose to a height in the northern islands of 1600 feet, and in Suderöe of 1400 feet above what is now the sea-level. Not only so, but the ice was so thick that it filled up all the fiords and sounds between the various islands of the archipelago, thus forming one compact *mer de glace* which flowed outwards in all directions from the dominant points, and discharged its icebergs into the surrounding ocean. If such were the state of the Færöe Islands in the concluding cold period of the Ice Age, it is but reasonable to infer that similar extensive ice-sheets flowed outwards from Iceland, Greenland, and Spitzbergen, into the Arctic Ocean, the temperature of which must have been depressed to a very low degree by icebergs and floe-ice, which, indeed, must have well-nigh choked it up. Is it possible that any one of the southern species which occur in the postglacial beds and present seas of Scandinavia could have survived such conditions? The answer, I think, must be in the negative.

Thus we seem driven to the conclusion that the visitors from southern waters which are now living in the northern seas, and which were at one time more plentiful, both as regards species and individuals, must have immigrated long after the severity of the latest glacial epoch had passed away. Their history is entirely postglacial. During the deposition of the postglacial shell-beds the sea was gradually retreating, and this continued until the land attained a considerably wider area than it now presents. The evidence for this we find in the "submarine forests and peat" of our own shores and the opposite coasts of France and the Low Countries. It is now generally admitted by geologists that these old forests indicate a time when the British Islands were united to themselves and the Continent. The purely geological evidence points to this conclusion and no other. No one doubts that the flora and fauna of our islands could only have immigrated by a land-passage, and as neither our animals nor our plants could have existed here during the last glacial epoch, it follows that they must be of postglacial age.

I have shown how we read in the postglacial shell-beds a history of the gradual change from arctic to temperate conditions. The same history is repeated by our peat-bogs, and it is clearly evinced by the present distribution of plants in North-western Europe. It will be remembered that underneath peat-bogs in various parts of Central Europe the traces of an arctic or northern flora have been discovered, principally by Mr. Nathorst. He has recorded them from Switzerland, Bavaria, Mecklenburg, Denmark, and Southern England. It is highly probable that some of these finds belong to the last glacial epoch itself, that is to say, that they represent the flora which characterised Central Europe at a time when the great *mer de glace* still occupied the basins of the Baltic and the North Sea. As the snow and ice disappeared from Northern Germany, Denmark, and England, the dwarf birches and arctic willows gradually crept north and overspread the barren grounds. At what particular point, and by what passage, the northern flora entered Sweden we do not at present know. No trace of that flora is found under the peat of the low-lying coast-lands of Scania and Southern Norway. It may be, as Mr. Axel Blytt has suggested, that those regions were still under water when the arctic willow and its congeners became established in Sweden. But if that were so, one might ask by what route that flora immigrated. Was it conveyed by chance ice-rafts from the German and Danish shores? This, although possible, is hardly likely. How, then, and at what time, did it enter Sweden? If it crossed to Sweden by a land-passage, that passage would date back to late glacial or early postglacial times. We might suppose that the movement of elevation which carried up the arctic shell-beds of Scania and Southern Norway was continued until a land-connection with Denmark had been effected, and that the arctic willow and its associates then passed over.[1] By and by, when the climate became milder, the arctic flora was succeeded by the temperate species, and shortly afterwards the land-connection disappeared, and the southern part of the Scandinavian peninsula was depressed for 150 feet or more, and thereafter the later postglacial shell-beds were formed. This view would explain several matters which at present are not very clear. It would account, in the first place, for the fact that the postglacial shell-banks, with their characteristic fauna, rest "unconformably" upon the arctic clays—there is no passage from the older into the newer series. The clays with arctic shells go down to the sea-level, and are there covered by the later shell-beds in such a manner as to indicate that some time must have elapsed between the formation of the two series. Then, in the second place, it would give a reasonable explanation of the appearance in the postglacial shell-beds of the remains of temperate species of plants. It is hard to believe that there was no land-connection between Sweden and Denmark before the formation of the younger postglacial deposits which cover the slopes of Enköpings *ås* or gravel-ridge, and in which it will be remembered remains of oak, willow, aspen, fir, etc., occur. The suggestion I venture to make, therefore, is simply this: that after the deposition of the latest shell-beds pertaining to the Glacial Period a land-connection obtained between Denmark and Sweden across which the arctic flora migrated; that this connecting link continued in existence until after the climate had so far improved that temperate species of plants gradually crept into Sweden; that thereafter the land again sank to a depth of 150 feet or more.

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[1] Gwyn Jeffreys's discovery of arctic littoral shells off the Shetland Islands, referred to in the text (p. 509) may possibly be connected with this supposed elevation of the Scandinavian peninsula in late glacial times. Possibly, also, the shell-bed referred to by Mr. E. Erdmann as occurring 100 feet below the level of the sea at Gothenburg may pertain to the same period. See *Geol. För. i Stockholm Förh.*, May 1876.

That the British area had some connection with the Continent —probably with Belgium[1] and North-Eastern France—in late glacial and early postglacial times may similarly be inferred from the presence in the peat of Southern England of the large pines described by Mr. Godwin-Austen.[2] It is hardly possible, I think, that pines could have endured the climate of England during the climax of the last glacial epoch. The only flora which was likely to cover the low grounds at that time would be dwarf birches and willows—such a flora, indeed, as Mr. Pengelly found in the clays of Bovey Tracey in Devonshire. And perhaps the nearest approach to that flora which we find at the present day appears in Spitzbergen, where, commingled with the prevailing arctic or glacial forms, we find certain species which range south of Germany (some of them even reaching North Africa), such as *Taraxacum palustre*, DeC.; *Eriophorum angustifolium*, Roth; *Poa pratensis*, L.; *Festuca ovina*, L.; *Cystopteris fragilis*, Bernh.; *Equisetum arvense*, L.; *E. variegatum*, Schleich. This land-connection of England with the Continent continued to exist long after arctic conditions of climate had vanished. And thus the northern and temperate species had ample time and opportunity to invade the British area in force.

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[1] If the "Sable Campinien" of Belgium be of marine origin and postglacial age, this would indicate a submergence in early postglacial times of a wide tract of country, for the beds in question extend south in Belgium as far as a line drawn from Dixmunde to Maestricht by way of Ypres, Courtrai, Audenarde, Alost, Malines, Louvain, and Hasselt (Dewalque, *Prodrome d'une Description Géologique de la Belgique*, p. 241). But the sands of the Campine are, as a rule, totally devoid of fossils, the only remains they have yielded being the bones and teeth of mammoth, rhinoceros, dog, horse, deer, etc. According to Dewalque they form the western prolongation of that great sheet of sand which stretches north into Holland, and is prolonged through Northern Germany along the borders of the Baltic. In other words, the "Sable Campinien" forms part and parcel of the great Northern Drift. In many places, however, the deposits are so loose and incoherent that they have been blown about by the winds, and thus it is impossible, says M. Dewalque, always to distinguish between the undisturbed and the re-arranged materials. The Belgian geologists have long been in doubt as to the true geological position of the "Sable Campinien," some holding it to be older, some younger, than the löss, while others have maintained that the two deposits are contemporaneous. Quite recently M. P. Cogels and Baron O. van Ertborn made some borings at Menin and Courtrai which show that in those places the "Campinien" overlies the "Limon hesbayen" or löss (*Mélanges géologiques*, Anvers, 1880). At Menin the "Campinien" was 26 feet, and at Courtrai 18 feet in thickness. This, however, is hardly sufficient to prove that the "Campinien" is younger than the "Limon hesbayen" throughout all Belgium. The formation of löss and of drift sand was not confined to one particular stage of the Pleistocene. Moreover, we have no assurance that the Campinien at Menin and Courtrai is not *remanié*. In any event, the Campinien is not a postglacial deposit, and there is not a shadow of evidence to show that it is of marine origin.

[2] Dr. Buchanan White suggests that winds and sea-currents might have carried to the English shores of the Channel the spores of mosses, lichens, and other cryptogamic vegetation, and perhaps even the seeds of some of the higher plants (see *Scottish Naturalist*, July 1879). If this be so, it would not be necessary to suppose that in late glacial or early postglacial times England had any connection with the Continent, that connection taking place at a somewhat later date.

Edward Forbes, in his classical essay on the geological relations of the fauna and flora of the British Isles,[1] has mapped out the plants into five types or groups, namely, 1, the Asturian flora of the west and south of Ireland; 2, the Devonshire type, occupying the south-west of England and a portion of the south-east of Ireland; 3, the Kentish type, developed in the south of England; 4, the Scandinavian type, almost confined to mountainous elevations; 5, the Germanic type, occupying the eastern part of the British Islands, and extending into and overlapping all the other provinces. It is this type, indeed, which gives its general character to the flora of our islands. The Asturian type of Ireland is represented by only a few plants which occur nowhere else in our islands. These are of a decidedly southern facies, most of them being characteristic of the coasts of Portugal and Northern Spain, although some occur also in France. Forbes was of opinion that these plants had migrated from Spain into Ireland, over a sunken land, in times long anterior to the Glacial Period. But our knowledge of the physical history of that period has greatly advanced since Forbes was lost to science, and it is very doubtful whether, if he had lived till now, he would have continued to hold the same view. The arctic conditions of the last glacial epoch forbid the supposition that the Asturian or Iberian flora, or even that of the Devonshire and Kentish types, could possibly have survived the Ice Age in Britain. The Asturian saxifrages and heaths of the west and south-west of Ireland grow upon mountains which are glaciated, and in the valleys of which morainic detritus abounds. The only flora which, as I have said, could possibly have outlived that Age in Britain would be high-alpine or Scandinavian. It was this flora which, upon the gradual disappearance of arctic conditions, slowly migrated north, ascending the mountains as the temperate group advanced and pressed it out of the low grounds. The Germanic, Gallican, and Iberian types may quite well have migrated during one and the same period, although it is most probable that the Germanic flora would be first on the march. But before the plants coming from Spain and Northern France could immigrate hither, it is evident that the British area must have been considerably more extensive than it is at present. Mr. Godwin-Austen, many years ago, showed that shell-sand (with littoral shells, such as limpets and periwinkles) occurs upon the western slope of the Little Sole Banks at a depth of 100 fathoms and more. This sand, he thinks, marks a former coast-line, when the shores of our area advanced to a point 180 miles south of Galley Head in Ireland, and some 200 miles west of Ouessant Island.[1] Again, Dr. Gwyn Jeffreys has recorded the occurrence of littoral shells of arctic species in about 90 fathoms of water off the Shetland Islands[2]—an interesting fact which goes to show that the North Sea may have vanished before the climate of Northern Scotland had quite lost its arctic character. The Irish Sea and the English Channel had thus ceased to exist, and in place of the North Sea there appeared a broad undulating plain, traversed by one or more rivers, which carried the tribute of our English and Scottish streams down to the deep gulf that circles round the south part of the Scandinavian peninsula, and even to the shores of the Northern Ocean, beyond the Orkney and Shetland Islands. In like manner the Inner and Outer Hebrides became united to the mainland of Scotland—the country that extended between them and the present shores of Ross and Sutherland being dappled with innumerable lakes, some of which were of great depth and width. In short, there was a return of those geographical conditions which we have every reason to believe characterised certain Interglacial epochs. [See Plate E.]

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[1] *Mem. of Geol. Survey of Great Britain*, vol. i. p. 336.

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[1] *Quart. Journ. Geol. Soc.*, vol. vi. p. 69.

[2] *Brit. Ass. Rep.*, 1867, p. 431.

The Scandinavian type in the British Islands, as is well known, attains its greatest development in the Scottish Highlands. It is less well represented in the southern uplands of Scotland, the hilly district of Cumberland, and the Welsh mountains, while Ireland shows a very meagre assemblage of alpine and subalpine forms. The Germanic type, on the other hand, is everywhere present, overspreading the other floras, and giving a general character to the vegetation. "Its scarcer forms," Forbes remarks, "are of much interest, from the clear manner in which they mark the progress of the flora, and the line it took in its advance westwards. Thus we find a number of species which are still limited to the eastern counties of England, while others, which have extended over considerable tracts or into several districts of England or Scotland, have not found their way to Ireland. It is remarkable," he continues, "that certain species of this flora, which flourish best on limestone, such as *Scabiosa columbaria, Sison amomum, Campanula glomerata,* and others, are not found in the limestone-districts of Ireland, and in like manner certain species, which everywhere, when found, delight in sand, as *Ajuga chamæpitys,* are also wanting in such Irish localities as are best adapted for them. The fauna which accompanies this flora presents the same peculiarities, and diminishes towards the north and west. This is very observable both among the native vertebrate and invertebrate animals. Thus, among quadrupeds, the mole, the squirrel, the dormouse, the polecat, and the hare of England (*Lepus timidus*) are confined to the English side of St. George's Channel, not to mention smaller quadrupeds. So it is also with the birds of short flight; so most remarkably, no less than half the species being deficient, with the reptiles; so also with the insects[1] and the pulmoniferous mollusca." These peculiarities of distribution Forbes has accounted for by supposing that Ireland was separated from England by the influx of the Irish Sea before the species, less speedy of diffusion, could make their way into the sister island, and this view has been repeated by every writer who has touched upon the question since the appearance of Forbes's famous essay. But a glance at the Admiralty's chart of the Irish Sea shows us that there is no necessity for inferring that the arrestment of the migration was due to submergence. Were the whole British area to be elevated for 600 feet or thereabout the Irish Sea would disappear, but Ireland would still be separated from England by a great and deep lake, averaging 25 miles at least in breadth, and extending from the head of what is now the Sound of Jura in Scotland down through the basin of the Irish Sea to a point between Braich-y-pwll in Caernarvon and Greenore Point in Wexford.[1] This lake, receiving the tribute of many Scottish, Irish, and English streams, would discharge a broad river from its lower end, which might well be impassable by many of the smaller vertebrates. That it was rather the presence of this lake and the obstacle of the Welsh Mountains than the premature appearance of the Irish Sea which arrested the westward migration of plants and animals, is shown by the remarkable fact pointed out by Professor Leith Adams,[2] that the mammalian fauna of Ireland agrees more closely with that of Scotland than of England; while Dr. Buchanan White has shown that Ireland has probably derived some of its alpine lepidoptera from Scotland. We may suppose that the temperate mammals gained admittance to Ireland from the west of Scotland, between which and the north of Ireland there was a broad land-connection. Some of the larger mammals, however, such as the great Irish deer (*Cervus megaceros*), may quite well have entered Ireland from the south, crossing the river that flowed south through St. George's Channel. But it may be questioned whether the reindeer immigrated by the same route. So far as the geological evidence goes, we have no reason to believe that at the commencement of the postglacial period the British area was much more extensive than it is at present. The sea was then retiring, as we know, from the low grounds of Southern Scandinavia and Scotland, and from the borders of East Anglia, and thus the probabilities are that when the Scandinavian flora had commenced its northward advance St. George's Channel still separated England and Ireland. This being so, the reindeer could not at that time reach the latter country. By and by, however, the Irish Sea gradually disappeared, and a land-connection took place between Scotland and Ireland, across which the alpine and sub-alpine flora and the reindeer would migrate. It is perhaps owing to the late appearance of this land-connection that the

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[1] My friend Dr. Buchanan White has recently discussed the distribution of the mountain-lepidoptera of Britain and its causes (*Scottish Naturalist*, July 1879). In this paper he gives an admirable résumé of the evidence relating to the introduction of the alpine or Scandinavian flora of our islands, and has traced in a very suggestive manner the route followed by the lepidoptera, which are now restricted to our mountain-regions. The facts and suggestions put forward in his paper are thus summed up:—

"1. The British Isles, being at one time subject to extreme arctic conditions, had no fauna or flora.

"2. At the close of the last glacial period they were peopled by plants and animals from Continental Europe.

"3. Most of these plants and animals reached Britain across the dry or nearly dry bed of the German Ocean.

"4. Plants necessarily arrived before animals; and of the former certain classes of cryptogamic plants, and the maritime and wind-fertilised species of the higher plants, were the first comers.

"5. The arctic and arctic-alpine plants and animals, being those that followed closest on the retreating ice, were amongst the earliest arrivals, and had a wide range through the country.

"6. From their present distribution in Britain it is probable that all the species (in question) did not enter Britain at the parts nearest Continental Europe, but that they reached it at various points on the present east coast.

"7. The distribution of the species [of lepidoptera] (treated of in this paper) is not co-extensive with that of their food-plants.

"8. Climate has been a chief factor in producing the present distribution.

"9. Ireland derived some of its insects from Scotland.

"10. At least some of the British mountain lepidoptera existed as species previous to the last glacial period."

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[1] See Admiralty's chart of East Coast of Ireland, No. 1824*a*; and *Great Ice Age*, Plate xii.

[2] *Proc. Royal Irish Acad.*, 2d Series, vol. iii. p. 99; *Proc. Royal Dublin Soc.*, 1878, p. 42.

Scandinavian type of vegetation is so poorly represented in the Hibernian flora. The climate, we may suppose, was already becoming milder, and the high-alpine forms were gradually vanishing from the low grounds, so that only a few of these could make their way south into Ireland.

A very general elevation of the land characterised the next stage of the postglacial period, and it is not difficult to follow the gradual improvement from arctic to temperate conditions. It was precisely such a change as we should now experience were we to start from the American shores of the Arctic Ocean, and, after traversing the Barren Grounds and the region of conifers, to enter upon the zone of deciduous trees. We see the British Islands at first surrounded by cold waters in which floating-ice abounds. Our mountain-valleys support considerable glaciers, and the winter temperature is severe. A scanty arctic and alpine flora of lichens and mosses and dwarf birch, with other northern forms, is sprinkled over the low grounds, and the reindeer is the most notable denizen of the land. At this time England is connected with the Continent, probably with Belgium and the north-east of France, but in Scotland the low-lying maritime districts are still to some extent under water. Ireland forms, as it does now, a separate island. The sea, however, is slowly retreating, and the cold of winter becoming less severe, and with the improvement of the climate plants and animals of more temperate types begin to appear in the south of England. Eventually all our islands are united, while at the same time a broad plain extends over the area of the North Sea, and connects Britain with Holland and Denmark. Before the great forest-vegetation had covered our country, the land, according to Forbes, would be in the condition of the Barren Grounds, bare and treeless, with the reindeer, the Irish elk, the urus, and species of bear, fox, wolf, hare, cat, and beaver, for its inhabitants. Vast herds of the Irish elk or deer then roamed over Ireland and what is now the basin of the Irish Sea and the Isle of Man, but they do not appear to have entered Scotland in any force; at all events, no trace of them as a rule is met with in the postglacial and recent deposits of that country, there being only one solitary recorded example of their occurrence, and that in the south-west of Ayrshire. A strong forest-growth at length overspread the country, extending into every district, and reaching even the remote regions of the Orkney and Shetland Islands and the Outer Hebrides. It was while these genial climatic conditions obtained that the Iberian plants found their way into the south and west of Ireland, and the Gallican forms immigrated across the area of the Channel to the south-east of Ireland and the south of England.

That the climate at this time was more genial than now is proved by a variety of considerations. It is shown, in the first place, by the former greater vertical and northerly range of arboreal vegetation. In the now treeless regions of the Outer Hebrides, the Orkney and Shetland Islands, and Northern Norway, the peat-bogs have yielded abundant relics of a vigorous forest-vegetation. Even the storm-swept Færöes were at one time covered with a bushy vegetation. During a recent visit to those islands, in company with my friend Mr. Amund Helland, I was much struck with the appearance in the peat of numerous roots and branches which, in the absence of the bark, we could not determine, although we thought they were most probably juniper. None that we noticed exceeded the thickness of one's wrist; but an intelligent trader told me he had frequently seen them as thick as his arm, and sometimes even as thick as his leg. At present the only shrubs in the islands are the few which stand within the garden-walls at Thorshavn, where they are carefully tended and protected. Yet the evidence of the peat proves that in postglacial times the climate was such as to permit of a plentiful growth of shrubs and small trees over all the less considerable slopes of the islands. A similar tale is told by the peat of Northern Norway; and even in Spitzbergen we are not without botanical testimony to the former prevalence of a milder climate than the present. When the Færöe Islands were plentifully clothed with shrubs and small trees, they could hardly have been subjected to the strong winds which now sweep over them, forbidding the growth of all arboreal vegetation. Now, as there can be no doubt that the "buried trees" of the Færöe Islands belong approximately to the same date as those of our own islands and North-western Europe, it seems impossible to resist the conclusion that the climate of those regions in the postglacial period must have been, *for some time at least,* considerably more genial than it is now.

This conclusion derives strong support from the very interesting researches of Mr. Axel Blytt into the cause of the present distribution of plants in Norway. He points out that in the coast regions of the province of Christiansand and Smaalene there are found a number of species which are either absent or very seldom found in other parts of the country.[1] Amongst these are some, he says, which are very rare, and known to grow in only one place in Norway. The majority of this group of coast-plants occur again in the south of Sweden, but they are absent in the Christianiafjord. Their distribution out of Scandinavia is chiefly in the maritime districts of Western and Southern Europe, down to the coast of Portugal and the Mediterranean; while in Scandinavia itself some are confined to the west coast of Norway.[2] The deep submarine trough which runs round the southern coast of Norway forbids, according to Blytt, the supposition that these plants could have entered Scandinavia directly from the old land-surface that now lies drowned in the North Sea; during postglacial times that deep trough would exist as a long and broad fiord.[3] Blytt concludes, therefore, that the plants of the west coast of Norway must have come by way of Denmark into Southern Sweden, and thence spread round the Christianiafjord to the west country. And seeing that the climate in the neighbourhood of the Christianiafjord no longer favours the growth of many of the plants in question, the inference is obvious that this has deteriorated since the immigration of the west-coast flora.

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[1] Such as *Quercus sessiliflora, Teucrium scorodonia, Jasione montana, Hedera helix, Rosa rubiginosa, Rubus thyrsoideus, R. Lindebergii, R. Radula, R. corylifolius, R. Wahlbergii, Cladium mariscus, Heleocharis multicaulis, Petasites alba, Pulicaria dysenterica, Atriplex farinosa, Filago minima, Gentiana pneumonanthe, Ajuga reptans, Berula angustifolia, Epilobium tetragonum, Agrimonia odorata, Trifolium procumbens, T. minus, Vicia cassubica, Coronilla emerus,* etc.

[2] Amongst these Blytt mentions *Asplenium marinum, Hymenophyllum Wilsoni, Carex binervis, Scilla verna, Erica cinerea, Conopodium denudatum, Meum athamanticum, Rosa involuta. Essay on the Immigration of the Norwegian Flora,* etc., pp. 27, 28.

[3] It is possible, however, that when the land reached its greatest extent, even that deep trough may have been vacated by the sea. But the soundings show that with such an elevation of the sea-bottom a long deep lake would occupy a

But the genial conditions that obtained for a time during the postglacial period are still more strikingly illustrated by the discovery made many years ago by the Arctic Expedition under Sir Edward Belcher. Sir Edward brought away from the shores of Wellington Channel (lat. 75° 32′ N.) portions of a tree which was found occupying the place of its growth, and of which he says, "I at once perceived that it was no spar, and not placed there by human agency; it was the trunk and root of a tree, which had apparently grown there and flourished, but at what date who will venture to say? It is, indeed, one of the questions involved in the change of this climate. As the men proceeded with the removal of the frozen clay surrounding the roots, which were completely cemented, as it were, into the frozen mass, breaking off short, like earthenware, they gradually developed the roots, as well as what appeared to be portions of leaves and other parts of the tree, which had become embedded where they fell, and now were barely distinguishable—at least, not so much as some impressions on coal—to the casual observer. . . . Two neighbouring mounds were also dug into, but they proved to be peat—doubtless other stumps and vegetable matter,—the only remaining traces of what might at some distant period have been a forest. All the surrounding earth and tufts of grass indicated this spot to have been the bottom of some lake or marsh."[1] Dr. Hooker pronounced the wood to belong to a species of pine, probably *Pinus* (*Abies*) *alba*, the most northern conifer, which advances as far north as the sixty-

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large part of the trough in question, and this would prove almost as effectual a barrier as the sea.

[1] *The Last of the Arctic Voyages*, vol. i. p. 380.

eighth parallel. The structure of the wood was found to differ remarkably in its anatomical character from that of any other conifer with which Dr. Hooker was acquainted, and the peculiar conditions of an arctic latitude—long months of day, succeeded by long months of night—seemed to him to afford an adequate explanation of the appearance presented.[1]

Thus there are several lines of evidence which seem to lead to one and the same conclusion—the testimony of the plants supporting and confirming that of the marine mollusca. It will be observed that the view of a postglacial warmer epoch does not rest upon the former occurrence of one or two species far north of their present range, of which we have even in our own day some notable examples, but is based upon a much broader foundation. And I am much strengthened in the opinion I have been led to form by finding that Sir Joseph Hooker has independently come to similar conclusions. Upon the publication of a short outline of the subject in a recent number of *The Scottish Naturalist,* Sir Joseph was good enough to write me as follows:—"The case for a postglacial warmer epoch than the present is, I think, fairly made out, though too much stress cannot be laid upon the presence or absence of pine and other trees, which in small areas may depend upon very local causes. For instance, it is hard to say why certain parts of Scandinavia are clothed with pine, others with fir, others with beech, and still others with oak, quite irrespective of latitude and isothermals; and there are considerable areas in South Scotland where I am assured the Scotch fir cannot be induced to grow at all, and where conifers of much warmer climates thrive. The distribution of forest trees (and other plants) is, for a considerable distance towards their polar and tropical limits, exceedingly capricious; and where two or three species of trees of somewhat similar powers of endurance co-exist, they are apt to replace one another, so to speak, without any definite relation to the extreme limits to which they are individually able to attain. One of the most instructive results of Nares's Expedition was the evidence it brought of a flora in 81°-82° N., containing plants of a much less rigorous climate and latitude, one of which (*Andrasace septentrionalis*) is found nowhere within 10° of the latitude it there attains. Had it been found *fossil* only, it would have been regarded as unquestionable evidence of a change of climate. My friend, the late Dr. Thos. Thomson, had similar views to yours as to a warmer postglacial epoch, though probably, like my own, they were never formulated."

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[1] *Op. cit.* p. 381.

Intimately connected with the question of postglacial climate is that of the origin of the floras of the Færöe Islands, Iceland, and Greenland. The list of Færöe plants given by Trevelyan,[1] and Dr. Lauder Lindsay's catalogue of the Icelandic flora,[2] show that the Germanic type is strongly represented in those regions. By what means and at what time did these islands receive their vegetation? Edward Forbes has not hesitated to maintain that the presence of the Germanic types proves that there must have been a land-connection with the British area to have permitted the immigration of the plants in question. There is, indeed, no other way of accounting for their presence.[3] Again, Sir Joseph Hooker has shown that the flora of Greenland is essentially Scandinavian or North-west European in character, hardly any of the peculiar plants of the American Arctic sea-coast and polar islands crossing Baffin Bay and Davis Straits. And he accounts for the fact of its Scandinavian character by inferring "that at a period previous to the Glacial, a flora common to Scandinavia and Greenland was spread over the American polar area; and that on the accession of the cold of that period this flora was driven southward, and was affected differently in different longitudes. In Greenland many species were exterminated, being, as it were, driven into the sea at the southern extremity of the peninsula, where only the hardiest survived. On the return of warmth the Greenland survivors migrated northward, peopling the peninsula with the hardiest of the species of its former flora, unmixed with American species, and unchanged in aspect, from never having been brought into competition with those of any other flora."[1]

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[1] *Edin. New. Phil. Journ.*, 1835.

[2] *Trans. Bot. Soc. Edin.*, 1860, p. 114.

[3] Of course it is not denied that there are many other ways and means by which plants have become dispersed. Winds and ocean-currents have done their part, and doubtless birds have performed theirs. But the regions referred to could hardly have received their flora in this way. The flora of Greenland is much more closely connected with that of Scandinavia than with the flora of the adjacent American coast. But if the plants had been carried by wind, sea, or birds, the reverse ought to have been the case. So also with the floras of Iceland and the Færöes; had they been carried in a haphazard way across the sea, they would not have presented such a close analogy with the flora of North-west Europe. The plants of the Færöe Islands and Iceland are just such as ought to occur if continuous, or nearly continuous, land had permitted their immigration.

From what I have said as to the conditions that obtained in North-west Europe during the latest glacial epoch, it is hardly possible that the flora of Greenland can date back to so early a period as Sir Joseph supposes. That of the Færöe Islands is certainly of postglacial origin, for the ice of the last cold period completely enveloped the whole group, and must have destroyed every vestige of their vegetation. I have not visited Iceland, but it is well known that the marks of glaciation are conspicuous there, not only in the interior, but upon the lower grounds near the coast.[2] Indeed we may be sure that Iceland could hardly have wanted its enveloping *mer de glace* at a time when the Scandinavian and Scottish ice-sheet filled up the North Sea, and a thick mantle of ice smothered the Færöe Islands. But even if Iceland were not entirely buried under an icy covering, yet the climatic conditions of the last glacial epoch must have sufficed to destroy such a flora as it now possesses. And the same must have been the case with Greenland. Indeed I do not see how it is possible to resist the conclusion that the floras of all those high latitudes must have been introduced since the close of the Glacial Period. And as the plants could only have migrated over a land-surface, we are compelled to infer that in postglacial times the Færöe Islands, Iceland, Greenland, and Spitzbergen also, must have been united to the European continent.

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[1] *Gardeners' Chronicle*, August 1878. See also *Trans. Linn. Soc.*, 1860.

[2] W. Sartorius von Waltershausen appears to have been the first to detect glacial striæ in Iceland, during a visit in 1846. He traced groovings and furrows from the sea-level inland up to a height of more than 2000 feet; they were not confined to the valleys, but appeared likewise on the flat basaltic plateaux. He also mentions the occurrence of erratics of granite, and certain other crystalline rocks, upon the north and north-east coasts of Iceland. As Iceland appears to be composed entirely of volcanic rocks, such as basalt, trachyte, tuff, etc., the probabilities are that the stones and blocks referred to by Waltershausen have come, as he suggests, either from Greenland or Scandinavia. See *Natuurk. Verh. Holl. Maatsch. Wettensch.*, Haarlem, Dl. xxiii. pp. 76, 79. R. Chambers has also noted glacial markings in Iceland (*Tracings in Iceland and the Færöe Islands*, 1856, p. 49), and references to their occurrence appear in most recent books of travel in the island.

It is hard to tell what amount of elevation would suffice to bring about such an union at present. The soundings in the Arctic Ocean are few and widely separated. We know that a trough, which in places exceeds 500 fathoms in depth, lies between the Outer Hebrides and the Færöe Islands. But at one place this deep hollow appears to contract to a width of not more than thirty miles, and it is quite possible that an elevation of less than 500 fathoms might produce a land-surface so nearly continuous as to permit of immigration by wind and ocean-currents, and by birds. An elevation of apparently less than 400 fathoms would join the Færöe Islands to Iceland, and the Danish Straits between Iceland and Greenland might perhaps be bridged with a similar or even a less amount. The sea between Norway and Spitzbergen appears to be comparatively shallow, not exceeding 200 fathoms or thereabout. In these speculations, however, we must remember that it is perfectly possible that the depression which brought about the isolation of the regions in question may have been unequal—some regions sinking deeper than others. Even at the present day similar earth-movements are believed to be going on within the very area under review. Thus, while the shores of the Danish settlements in Greenland are slowly sinking, a part of the Swedish coast is supposed to be gradually rising. Again, in Scotland the presence of raised-beaches on the coasts of the mainland proves a recent gain of land, while the complete absence in the Outer Hebrides, the Shetlands, and the Færöe Islands, of any such deposits shows that those regions have either been stationary for a very long time, or else have undergone a recent submergence, the latter, as I believe, having been the case. Be that, however, as it may, the existing floras of Spitzbergen, Greenland, Iceland, and Færöe, seem to establish the fact of a postglacial land-connection with North-west Europe, at a time when, as the evidence I have adduced leads us to believe, the climate was more genial than at present. This conclusion, it will be observed, is not in accordance with the opinion of those who maintain that the cold of the Glacial Period was due to the elevation of land in high latitudes. But the fact is that the chief climatic vicissitudes of Glacial, Interglacial, and Postglacial epochs appear to have been quite independent of all movements of elevation and depression. Sometimes intensely arctic conditions coincided with elevation, but just as often the opposite was the case, as is proved by the presence of deposits with arctic shells in Canada, Scandinavia, and Scotland. On the other hand, while a genial climate now and then concurred with a period of submergence, as during the formation of the Postglacial shell-beds of Spitzbergen and Norway, it is no less certain that mild and genial conditions were frequently contemporaneous with a much wider extent of land-surface in northern regions.

It may be objected to the view of a great extension of land having obtained in the Postglacial Period that the time required for the geographical changes involved is greater than can be supposed to have elapsed since the close of the Glacial Period. To which it may be replied, first, that the data are insufficient to enable us to say what amount of depression has taken place, and, second, that we cannot calculate the rate at which the submergence was effected. It may be that an elevation of considerably less than 400 or 500 fathoms (2400 or 3000 feet) would connect Greenland, Iceland, and the Færöe Islands, with Europe, and it may have taken 20,000 or 60,000 years, less or more, to have brought about their isolation. We really have no reliable data to go upon. The rate of 2½ feet for each hundred years assumed by Lyell for the elevation of a certain region of Southern Sweden is no standard of measurement; the movement of depression which sundered Færöe, Iceland, and Greenland from our continent may just as well have progressed at the rate of five feet. In some places it may have been more, in others less; and it may have varied in degree at different times.

The traces of a mild and genial postglacial climate having been met with so far north as Greenland and Spitzbergen, it can hardly be doubted that Central Europe must also have participated to some extent in the same conditions, and rejoiced in a more equable climate than the present. But the direct proofs of this must necessarily be more difficult to detect. The presence of remains of trees in the peat of the Færöe Islands and the bleak and sterile coast of Wellington Channel speaks a language that no one can misunderstand, but the contrast between the present and the past must obviously be less striking in more temperate latitudes. Nevertheless, it cannot be denied that the abundant remains of large trees in the peat of Norway, Sweden, Denmark, Schleswig-Holstein, Holland, Northern Germany, and Finland, betoken the former existence of much more extensive forests than can possibly have flourished within the historical period. Even after making every allowance for the destruction of trees by man's hand during and since the days of the Roman Empire, we must admit that a very large proportion of the buried timber must date back to very distant prehistoric times. And the great antiquity of the old buried forests is in many cases proved by the fact that the human relics which they have yielded are frequently of Neolithic age. The animal remains furnished by them are of the common temperate species, which are still in large measure indigenous, and do not aid us, therefore, in coming to any definite conclusion as to the climatic conditions. But the fact that the red-deer was in postglacial times an inhabitant of Kurland would lead us to conclude with Professor Grewingk that the climate of that region must have been milder then than now. The whole of Northern Europe was covered, as it would appear, with dense forests—overspreading wide tracts which within historical times have always been bare and treeless. Extensive areas which are now submerged then existed as dry land, and were probably clothed with as thick a matting of forest as those portions of the ancient land-surface which still remain above the sea-level. The wooded region stretched north up to and even beyond the Arctic Circle, although, as one might have expected, the trees in those high latitudes were generally scrubby and dwarfed. From these facts I think it may be fairly concluded that the winter season of the mild postglacial epoch must have been generally genial, while the temperature of summer, owing to the greater extent of land, may have been somewhat warmer. From the circumstance that a woody vegetation covered such regions as the Færöe Islands, we may likewise infer an absence of violent winds; for, as a writer in a recent number of the *Quarterly Review* has remarked, it is to the long-continued cold winds and gales that the absence or scarcity of trees in the higher latitudes is probably due. The ice-fields of the polar regions were considerably reduced in extent, while continuous or nearly-continuous land, connecting Greenland with Scandinavia, shut off cold arctic currents and allowed the warm waters of the Gulf Stream to lave the shores and influence the climate of the higher latitudes. Under such climatic conditions it is not surprising that the mammalian fauna of temperate regions like Britain and Northern Germany should have greatly abounded—and that several of the species should have attained a much greater size than is ever reached by them in our times. But none of the southern forms characteristic of the Pleistocene Period seems to have returned to North-western Europe. Hyæna, serval, elephant, rhinoceros, and hippopotamus had ceased to form a part of the European fauna. Yet the conditions were such as might well have tempted hither the great carnivores. We know, indeed, that the lion infested the mountains of Thessaly even within historical times, but its remains have never been met with in any of the postglacial deposits of North-western Europe. The general absence of the large carnivores in postglacial times was doubtless due to the disappearance of land-connections across the Mediterranean. The approaches to our preserves were effectually closed to these southern reivers.

The succeeding stage in the history of postglacial changes was marked by a gradual deterioration of climate, and the submergence of vast tracts of land in the north and north-west. The British area was insulated, and a like fate befell Greenland, Iceland, and the Færöe Islands. This insulation of our area prevented the immigration hither of many plants of an eastern derivation which subsequently spread into the neighbouring regions of the Continent, where they are now plentiful.[1] We have no reason to believe that these changes were suddenly effected. Probably the depression commenced during the preceding genial period—perhaps in the far north, and gradually extended southward, so that the separation of Greenland, and the isolation of the Færöe Islands and Iceland, may have taken place long before the North Sea crept in between Britain and the Continent. It is possible, indeed, that the broad space between Greenland and Scandinavia may mark a special area of depression—from the centre of which the downward movement may have diminished outwards in all directions. And this is not a mere conjecture, but is suggested by the fact already referred to, that the evidences of recent submergence are conspicuous in the north of Scotland, the Outer Hebrides, Orkney and Shetland, the Færöe Islands, and the north-west shores of Norway. Raised-beaches, which prove recent elevation, are common upon the coasts of England, Ireland, Central Scotland, and the southern margin of the Scandinavian peninsula. But north of those regions all the appearances betoken a recent submergence. There are no raised-beaches, nor, as a rule, have the waves had sufficient time to cut the rocks back so as to form conspicuous platforms between high- and low-water marks. Now and again, it is true, these may be observed, but it is only in cases where the rocks, by reason of their composition or structure, have lent themselves more readily to the action of the sea. As one boats along the rocky shores all the phenomena seem suggestive of a very recent loss of land, and the inference I would make is simply this, that the movement of depression which separated Iceland and Greenland from Europe has continued, with perhaps no interruption, from the genial postglacial epoch to the present day. I have not forgotten the important fact that the postglacial submergence carried down Central Scotland for some 50 feet or so below its present level, and that the regaining of this belt of coast-land from the sea would seem to indicate not only an interruption of the great northern depression, but a movement in the opposite direction. It is not so certain, however, that our later raised-beaches owe their origin to earth-movements. M. Adhémar and Dr. Croll have shown that the sea-level may rise without any movement of the land itself. They have pointed out that a great accumulation of ice in northern regions, such as that which characterised the glacial epochs, would of itself cause a rise of the sea by displacing the earth's centre of gravity, and it is quite possible, as Dr. Croll has suggested, that some of our recent raised-beaches may indicate periods when the ice of north polar regions attained a considerable augmentation, while, at the same time, the ice of the Antipodes suffered a corresponding diminution. Now, it is the fact, as I have proved, that the climate of Scotland during the 50-feet-beach was considerably colder than it is now; and I believe that this will be found to hold true of a much wider area. It is therefore quite possible, as already remarked, that the great northern depression may have been going on without interruption from the genial postglacial epoch down to our own era—the more recent raised-beaches being likely enough due to oscillations of the sea-level itself, and not necessarily to movements of the land.

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[1] As examples, Professor Engler gives the following list of species :—*Anemone ranunculoides*, L., *Hepatica triloba*, Chaix, *Thalictrum angustifolium*, Jacq., *Corydalis cava*, Schweigg. and Koerte, *C. fabacea*, Pers., *Viola mirabilis*, L., *Dianthus superbus*, L., *D. Carthusianorum*, L., *Tilia platyphyllos*, Scop., *Geranium palustre*, L., *Acer platanoides*, L., *Genista germanica*, L., *Astragalus Cicer*, L., *Lathyrus vernus* (L.), Bernh., *Potentilla alba*, L., *Sambucus racemosa*, L., *Melampyrum nemorosum*, L., *Abies alba*, Mill., *Picea excelsa* (Lamk.), Lk.—*Versuch einer Entwicklungsgeschichte der Pflanzenwelt insbesondere der Florengebiete seit der Tertiärperiode*, I Theil., p. 182.

The submergence, which in Central Scotland attained some 50 feet, appears to have been somewhat less in Ireland and England, and on the opposite shores of the Continent. I am not aware that the shells and other marine exuviæ which occur in the raised-beaches of Ireland and England afford any indubitable evidence of colder seas than now lave our shores. In the Scottish raised-beaches we have remains of the large Greenland whale, but the shells belong to species all of which are still living in the adjacent seas. The larger size attained by some of these shells, and the greater abundance of certain species, such as *Scrobicularia piperata*, would even seem to afford testimony to a formerly higher temperature, but such shells may be looked upon as survivors from the previous mild and genial period—they come into the same category as the Mediterranean species, which are still dredged in our seas. The cold was not such, in fact, as to affect the marine fauna to any considerable degree. But that the sea was somewhat colder seems to be indicated by the fact that the Greenland whale and the walrus ranged as far south as the coast of Lincolnshire. The change of climate, however, is more strikingly evinced by the re-appearance in Scotland of local glaciers, torrential streams, and rivers laden with glacial mud. That Scotland was alone in this respect can hardly be believed: if considerable glaciers occupied the mountain-valleys of the Highlands and Galloway, the Cumberland district and Wales could hardly have escaped having their perennial snow-fields and glaciers, and I should expect evidence of the same in the Irish mountains. I think it is highly probable, therefore, that the small moraines which occur at the heads of many of the upper valleys in those regions ought to be assigned to the same stage of the postglacial period as the similar relics in Scotland. The perfect state of preservation of these moraines, and the extreme freshness of the associated glacial markings, have always been difficult to reconcile with the belief that these date back to so remote a period as the close of the Glacial Period. But if they really belong, as I have endeavoured to show, to postglacial times, this difficulty vanishes, and several other enigmatical appearances receive a reasonable explanation.

Whether any glacial deposits pertaining to this period can now be identified in Norway and Sweden I cannot say, but it seems not improbable that some of that unfossiliferous sand and clay which cover the postglacial shell-beds over considerable areas in the low grounds of those countries may be of the same age as the older Carse-clays and late moraines and torrential gravel and sand of the Scottish series. And perhaps evidence will yet be forthcoming to show that a not inconsiderable advance of the glaciers took place in Norway in postglacial times. As yet, however, I am not aware that any trace of this has been recognised.

The climate during the formation of the 50-feet beach was not only cold, it was also extremely humid. Extensive areas which were formerly covered with forests were now dismantled of trees, and converted into marshes and morasses. And this change was not confined to maritime and mountain regions, but characterised the inland low-lying districts as well. Neither was it restricted to the area of the British Islands. Buried trees, as we have seen, occur in the peat everywhere throughout Northern Germany and adjacent regions. It was the very general distribution of these trees in the peat-bogs throughout all North-western Europe, which led me a number of years ago to infer that their destruction and entombment had been due to changed climatic conditions. And I am gratified to find that in this opinion I have the support of the accomplished Norwegian botanist, Axel Blytt, who from a study of the present distribution of the plants of Norway, and an examination of the peat-bogs, has independently come to the conclusion that they afford strong evidence of alternate dry or continental and wet or insular climates, having prevailed throughout the Postglacial Period. It cannot be denied that the mere separation of Britain from the Continent, and the reappearance of the Irish Sea, the English Channel, and the German Ocean, would of themselves produce a deteriorating effect upon the vegetation, especially in what are now maritime regions, but the very general destruction that befell the forests of the inland districts can hardly be due to that submergence alone. That the climate had become considerably colder, may reasonably be inferred from the reappearance of snow-fields and local glaciers in Scotland; and that it was also wetter, may be gathered from the fact that peat-bogs then overspread wide areas, in which nowadays they do not grow, but are mouldering more or less rapidly away.

The gradual disappearance of this cold and inclement epoch was marked by the slow retreat of the sea. The climate at the same time again favoured the growth of great forests—the remains of which are traced not only in the peat of our inland districts, but even in that of the maritime regions. We can hardly doubt that at the time when those trees were growing the land extended farther out to sea—in other words, the sea had retreated to a lower level than its present tide-mark. The buried trees in the peat of the English coast-lands bear emphatic testimony in this direction. Distinct traces of this second forest-growth are observable, as we have seen, in the inland districts. It is somewhat noteworthy, however, that while in Scotland oak is common at the bottom of the peat-bogs, not only in the lowlands, but even in upland and highland areas, the same tree appears to be generally wanting in the upper forest-layers, at least in the higher-lying parts of the country, and this rule holds true also for many lowland districts. Mr. Kinahan and others have made the same observation in Ireland. The most characteristic tree of the upper forest-layers in the peat-bogs of Scotland, more especially in the upland districts, is the pine (*Pinus sylvestris*), and this is the case also in Ireland. Mr. Blytt has recorded precisely the same fact in south-western and southern Norway. In those regions oaks and alders occur at the bottom of the bog, which is of variable thickness and formed of aquatic and marsh-loving plants. Above this under portion comes a second forest-layer composed chiefly of pines, which are in their turn buried under a second bed of sphagnum-peat. Lindeberg and Olbers tell us of exactly similar phenomena in the peat-bogs of Scania. There, as in Norway, the bottom forest-beds are composed of leafy trees, while the upper ones are principally coniferous. I have searched through many papers and books descriptive of the peat-bogs of Holland, Schleswig-Holstein, and Northern Germany, but cannot find that the same succession is as well marked in those regions. Very often, indeed, no discrimination is made between the trees which have come from the lower and upper parts of the peat, the writers simply stating what kind of trees are met with. I cannot doubt, however, that if the succession had been as conspicuous as it is in Norway and Sweden, so remarkable a circumstance would not have been overlooked.

How are we to explain these phenomena? It is obvious that they are too general to be accounted for by merely local causes. If the bottom peat-beds be due to a formerly prevalent cold and wet climate, we can hardly escape from the conclusion that the upper layer of peat points to a recurrence after some interval of similar conditions. The presence of the upper forest-layer shows that the wet period came at last to a close, and was succeeded by a drier climate favourable to the growth of trees. And from the fact that in many parts of Scotland, Ireland, and Scandinavia, the forests which then overspread the land were composed in large measure of pine and birch, we may reasonably infer that the climate was not so mild as during the growth of the more ancient forests, the remains of which occur at the bottom of the bogs.

The subsequent destruction of these later forests and their burial in sphagnum-peat indicate a relapse to ungenial and wet conditions. And it is suggestive that this change was followed or accompanied by a rise of sea-level and the submergence of forest-covered tracts in many maritime regions. Most of the so-called submarine forests which appear upon the low shores of our own and neighbouring lands belong to the second forest period, although not unfrequently both upper and lower forest-beds are exposed upon the same beaches. The whole subject of these successive forest-beds, with their intervening layers of peat, has been admirably worked out by Blytt, who is of opinion that the evidence warrants him believing in at least three rainy periods, when peat formed abundantly, separated by intervening dry periods, during which the peat-mosses dried up and were overgrown by forests. My observations in Scotland go a long way to support Blytt's theory of alternating dry and rainy epochs, but I cannot at present detect any evidence of more than two rainy periods in postglacial times. The postglacial period, however, was doubtless ushered in by cold and wet conditions, during which the arctic-alpine flora migrated north from the low grounds of Central Europe. The first rainy epoch of Blytt would thus correspond with the close of the Glacial Period and the commencement of the Postglacial Period, the two succeeding rainy epochs occurring in late postglacial and recent times.

The reader will not understand me to mean that the forests of North-western Europe were completely overthrown and buried in growing peat during each successive rainy period. There seems no reason to doubt that many wide tracts continued to support a forest-vegetation from the beginning of what we may call the first Age of Forests down to historical times. All that is sought to be maintained is simply this, that during the recurrent wet periods the forests were restricted in their horizontal and vertical range. They disappeared from wide tracts in the low grounds where they had formerly flourished, and were no longer able to sustain themselves at the higher elevations of the land. It must further be admitted that many of the ancient forests owe their overthrow to the hand of man. In our own country and in Germany the Romans are very generally credited with this work of destruction, but the peat-bogs with buried trees which can be proved to date down to so recent a period are much less numerous than has been supposed. The mere occurrence of Roman relics in peat is no proof that the trees which underlie that peat were growing in Roman times. Scottish antiquarians have gone on repeating one after the other the tale of Roman destructiveness, and have pointed to the presence in the peat of "camp-kettles," wooden roadways, and so forth, as evidence that the bogs must have originated from the overthrow of our forests by the legions; but, as already mentioned, many of these relics are now known to belong to the Bronze Period, and their position in the peat only shows that the bogs had already become unstable wastes long before the entrance of our Roman civilisers. Professor Grisebach has likewise shown that in Northern Germany much of the peat is of prehistoric antiquity, and Blytt has come to the same conclusion in regard to the peat of Norway. Nevertheless it is not denied that the Romans destroyed much woodland, and that our own people in more recent times continued to clear the land of its great forests. The names of places often testify to the former presence, even in late historical times, of considerable forests; and now and again one comes upon a country rhyme that seems to tell a like tale. Such are the lines quoted by Steele[1] as being current in the parish of West Calder, Midlothian:—

> "Calder wood was fair to see
> When it went to Cameltree;
> Calder wood was fairer still
> When it went o'er Crosswoodhill."

Again, the old statist of the parish of Banff says that in the now treeless maritime district the following distich is repeated by the country people:—

> "From Culbirnie to the sea
> You may step from tree to tree."[2]

In the Rhondda valley, South Wales, I have heard it said that "a squirrel could at one time travel from Treherbert to Pontypridd without touching the ground." This reminds one of the similar statement said to occur in an old document at Fürstenau in Osnabrück:—"Ein Eichhörnchen könne von Baum zu Baum springend von dort bis Lingen gelangen."[3]

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[1] *The Natural and Agricultural History of Peat-moss or Turf-bog*, etc., p. 383.

[2] Sinclair's *Statistical Account of Scotland*, vol. xx. p. 332.

[3] A squirrel springing from tree to tree can go from here to Lingen.

Fürstenau is distant some fourteen or fifteen miles from Lingen, and the intervening country is now bare of trees. I have but little faith, however, in the statements made in many of our local and county histories as to the wooded condition of Scotland in early historical times. Some of these statements can be shown by documentary evidence to be untrue, while others are unsupported by any proof. There can be little doubt, I think, that most of the stories in question have been suggested by the appearance in the peat-bogs of trees which have evidently grown *in situ*. If these buried trees had never been observed, we in Scotland should probably have heard very little of the demolition of ancient forests by the Romans or our "auld enemies of England."

An examination of the Scottish peat-bogs has led me to believe that we are now living in a dry period, for the peat is wasting away generally throughout the country, the rate of decay far exceeding that of growth and increase. And there is legendary and documentary testimony to show that the growth of many of our peat-bogs had already been arrested at a very early date, for the appearances described or incidentally referred to clearly betoken that the bogs had assumed a wasted aspect long before the general adoption of our present systems of drainage. I strongly suspect, therefore, that that rainy period to which I attribute the destruction of by far the larger portion of the buried trees in the upper part of our peat-bogs had passed away or become largely modified even as far back as the Roman occupation. Agricultural progress, however, has so greatly interfered with natural operations that it is impossible to say to what extent the changed conditions are due to a lessened rainfall. Mr. Blytt's observations in Norway have led him to similar conclusions. He thinks that the present is somewhat drier, the peat of the last rainy period being sorely wasted and decayed, even in the rainy district of Floröe, where the remaining masses of sphagnum are overgrown with lichen and heather. In numerous places, indeed, the bogs are often entirely covered with heather and small trees. And there are many signs, he says, that the continental species of plants—those which flourished most luxuriantly during the dry periods—have again begun to extend themselves.

To what extent the geography of Southern Europe was affected in postglacial times there is no evidence, so far as I know, to indicate. Some of the proofs of recent submergence and emergence upon the coasts of the Mediterranean may possibly be contemporaneous with those evidences of elevation and depression which are so marked in North-western Europe, but to what extent this may be the case I cannot even conjecture. The facts have never been systematically collected and compared, and considerable complication arises from the circumstance that the oscillations of level appear often to have been comparatively local, as might have been expected would be the case in a region where the volcanic forces continue to show some activity. The land-connections that formerly joined Europe to Africa probably disappeared in late glacial times. We have no evidence, at all events, to show that they endured down to the postglacial period. Thus, it would seem that the most interesting and striking traces of postglacial climatic and geographical changes are in large measure confined to North-western Europe. We must not forget, however, that such climatic changes as we have passed in review would be much less strongly marked in lower latitudes than our own. The farther south we go upon the Continent, the less likely are we to come upon conspicuous evidence of postglacial mutations of climate. It does not follow, however, that because such evidence has not yet been detected in Southern Europe, it does not exist. It will possibly be hard to find, and should it eventually be discovered it will be botanists and zoologists rather than geologists that we shall have to thank for the discovery. The carrying on of the tale of postglacial changes must indeed be resigned to the former, for notwithstanding all that has been done in the study of geographical botany and zoology, much yet remains to be accomplished to clear up the obscurities which still becloud the latest phases of geological history, and doubtless a promising harvest of discovery awaits the labours of the philosophical naturalist in this field of inquiry.[1]

At what stage of the Postglacial Period did Neolithic man enter our continent? There is no reason to believe that he made his appearance before the climate of Central Europe had lost its arctic character. His relics in that region are never found associated with remains of the arctic or northern group of mammals. But man was certainly contemporaneous with the reindeer in the north of Scotland. This, however, may be no proof of extreme antiquity if it be true, as some writers suppose, that the reindeer was hunted in Caithness by the Jarls of Orkney in the twelfth century. From the fact that remains of this animal have never been found associated with Neolithic relics in Central or Southern Scotland, we may reasonably suppose that it had already retired to the uplands of the north before the advent of the Neolithic people. How far south it ranged upon the Continent in Neolithic times we cannot tell. No trace of it has been found in connection with the lake-dwellings of Switzerland or the kitchen-middens of Denmark. Had it been still a denizen of Central Europe in early Neolithic times we might well have expected to meet with its remains in some of the numerous relic-beds of the period, and their total absence, therefore, seems to indicate that the climate had by that time entirely lost its arctic character. I do not forget that Cæsar mentions the reindeer as occurring in the great Hercynian Forest of Northern Germany, but from his description, which is incomplete and incorrect, some writers doubt if he ever saw it. But if it be true that it existed in Caithness so late as the twelfth century, it is to say the least not unlikely that in Cæsar's time it may have ranged into Northern Germany. During the mild and genial epoch which supervened in postglacial times it may have been quite unknown in Germany, but when the climate again became colder, and local glaciers existed in the mountain-valleys of Scotland and other regions, from which they have since disappeared, the reindeer may have again ranged farther south. And this may explain its absence from the Neolithic deposits of Central Europe and its presence at a later date in the Hercynian forest. I do not think, therefore, that the occurrence in comparatively low latitudes of reindeer remains along with human relics (imbedded in postglacial and recent deposits) is necessarily any proof of great antiquity.

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[1] There is much that is highly suggestive to the geologist in Professor Engler's recently published work (*Versuch einer Entwicklungsgeschichte der Pflanzenwelt*, etc.), and he accounts sufficiently well for the present general distribution of the flora. He admits, however, that a wide field still lies open for the working out of the details. Should the views of postglacial climatic and geographical changes set forth in these pages eventually be established, they will, I think, tend to modify some of Dr. Engler's conclusions. The modifications of the flora brought about by the vicissitudes of Glacial times are so strongly marked that they must tend to obscure the later changes induced by the less-pronounced climatic mutations of the Postglacial period. Nevertheless, I cannot doubt that a detailed analysis of the botanical evidence would show that the phenomena characteristic of the postglacial deposits of Northern and North-western Europe have their analogues in the present distribution of the plants of the middle, and perhaps even of the southern, regions. It is also much to be desired that botanists should work out more fully than has yet been done the structure of peat-bogs. The admirable results already obtained by Steenstrup, Nathorst, Blytt, Fliche, and others, only show how much more yet remains to be accomplished. It is not too much to say that the history of the passage from Glacial to Postglacial times is still in large measure locked up in those bogs and moors which cover such vast areas in our continent.

If we confine our attention for the moment to the geological evidence, we find that Neolithic man was certainly an occupant of the British area during the genial postglacial period, for his relics occur again and again in the lower forest-layers of our peat-bogs, both in the inland and maritime districts, and the same is the case in the equivalent accumulations of the Continent. But Neolithic relics have not yet been met with at a lower horizon—they appear to be wanting in those freshwater layers under the bogs in which the arctic willow and its congeners occur. So far, then, as the evidence at present goes, we cannot say that Neolithic man appeared until the climate had lost its arctic character—forests of pine and oak had overspread Germany, Denmark, Scandinavia, and Britain, by the time he immigrated.[1] The polar willow and the arctic-alpine flora had crept to higher latitudes and greater elevations, and the pine, followed by the oak, had occupied their places when Neolithic man became a denizen of Central and North-western Europe. From the appearance of his relics at the very base of the oldest postglacial forest-bed in Britain, it may reasonably be inferred that he was a native of this country when it still formed part of the Continent. The genial epoch during which the Færöe Islands, Iceland, and Greenland, received their flora had not yet passed away. Immense forests of oak still covered the low grounds of Scotland and the maritime districts of Norway, and dense groves of the same tree extended over vast areas in Holland, Denmark, and Northern Germany. It is probable, however, that the great movement of submergence which was eventually to result in the isolation of the British area had already made considerable progress, and the climate at the same time was gradually becoming wetter and colder.

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[1] It is often said that the succession of arborescent vegetation in the forest-bogs of Denmark does not quite tally with that which characterises the peat-bogs

By and by, as we know, the North Sea made its appearance, and the sea reached a higher level upon our shores than it now attains. Neolithic man then lived upon our coasts, and gradually accumulated his kitchen-middens. The climate was wet and cold, local glaciers appeared in many mountain-valleys, the forests decayed, and bogs continued to encroach upon the wood-

of other countries in Europe. This, however, is a mistake. It is true that in the peat of Britain, Norway, Sweden, and Germany, we find the lower forest-layer composed partly of oaks and partly of pines and other trees, whereas in the Danish bogs the oak lies above the pine. But the Danish bogs are somewhat peculiar in their structure. The pine was doubtless the first tree to form forests in the low grounds of Northern Europe, from which it gradually retired as more genial conditions supervened; and if all our forest-bogs had been formed in depressions like those of the Danish *Skovmoser* we should most probably have found the pine occupying the bottom position. But, as most of our forests grew upon open ground, the trees would rot and decay as they fell, and this process would continue until the pine had been gradually supplanted by the oak, the former, however, continuing to flourish in suitable localities. When at last a wet period supervened and the forests decayed and were buried in peat, the pine and the oak would be found upon one and the same horizon, each occupying the position which had been most suited to its requirements. The Danish bogs seem to have existed as marshes from the close of the Glacial Period, so that they contain an uninterrupted record of the changes; while most of our bogs, on the other hand, did not come into existence until after the oak had spread abundantly into the most northerly regions.

lands. Pine forests grew here and there upon the low grounds of Central Scotland, and the same appears to have been the case in Denmark, as we infer from the presence of the capercailzie in the Danish kitchen-middens. But the prevailing character of this period was the great destruction of the forests and their entombment in growing peat. Thus the geological evidence would lead us, in opposition to the views of some archæologists, to assign the Danish kitchen-middens to a comparatively late part of the Neolithic period. They are certainly of much more recent age than the Neolithic relics which have come from our oldest submarine peat-beds, and from the lowest forest-layer of our deepest inland bogs.

After this cold and wet epoch had passed away it was succeeded by more genial conditions, during which wide areas of marsh-land became dry, and were overrun by a new forest-growth, consisting in the British Islands largely of pine—at all events in Ireland, Northern England, and Scotland, and the same was the case in the Scandinavian peninsula. The sea had now retreated upon our shores to a somewhat lower level than the present, and it was probably at or about this time, or possibly even sooner, that a knowledge of bronze was introduced to Britain. On the Continent that knowledge would appear to have been earlier acquired, but the geological evidence is too slight and incomplete to enable us to say at what particular stage of the Postglacial and Recent period the Bronze Age commenced in Europe. If we may judge from the evidence furnished by the Danish peat, that commencement may date back to the close of the genial postglacial epoch—to a time when oak forests still covered wide areas in those maritime districts of North-western Europe, which at a later period became in large measure bared of trees, and overspread with boggy wastes.

The second Age of Forests, represented by the upper forest-layer of our peat-bogs, was followed by a relapse to colder and wetter conditions, when broad areas of tree-covered districts were converted into marshes. To this date must be assigned the decay of most of the great pine forests which formerly flourished over extensive areas in Ireland, Scotland, the north of England, and Scandinavia, and the overthrow of the buried trees of the upper forest-layer in the peat of Holland, East Friesland, Oldenburg, Lüneburg, the Cimbric peninsula, Mecklenburg, Pomerania, etc. Probably the Iron Age began during this wet period, which was already passing away when the Romans came to occupy Britain.

The Postglacial and Recent accumulations of Southern Europe throw little light upon the problem of the correlation of the Neolithic, Bronze, and Iron epochs with the successive stages of the geological record. We have evidence, indeed, to show that considerable local oscillations have affected the borders of the Mediterranean area since the close of Pleistocene times; and that while some of those changes of sea-level took place probably during the Neolithic Age, others, again, certainly come within the Historical period.[1] But we have none of those more or less clearly-marked stages which distinguish the Postglacial and Recent deposits of the maritime districts of North-western Europe.

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[1] The most complete account of changes in the coast-line of Europe which are supposed to have taken place within historical times is that given by K. E. Adolf von Hoff; *Geschichte der durch Ueberlieferung nachgewiesenen natürlichen Veränderungen der Erdoberfläche* (1822-1834). In this work the author seems to have exhausted every historical and lengendary source of information, and many of the statements of old writers which he has unearthed are perhaps worth more consideration than they have yet received.

CHAPTER XXII.

CONCLUSION.

Résumé of results—Identity of Pleistocene or Quaternary Period with Preglacial and Glacial times—Alternations of cold and genial climates in Pleistocene Period—Testimony of fauna and flora—Palæolithic man lived through the Pleistocene Period—Testimony of the Pleistocene river-deposits as to climatic conditions—Evidence supplied by cave-accumulations—Glacial and Interglacial accumulations contemporaneous with river-gravels, etc., and cave-deposits—Distribution of ossiferous and Palæolithic river-deposits—Last cold epoch of Glacial Period closes the record of Pleistocene times—Palæolithic implements in Interglacial deposits at Brandon; in Pliocene or early Pleistocene beds of St. Prest—Pliocene and Miocene man—What became of Palæolithic man—Professor Dawkins's views—Objections to his hypothesis that the Eskimo are of the same race as Palæolithic man—Views of M. Quatrefages and other French savants—Climatic and Geographical conditions of Postglacial Period—Age of the archæological periods—Dr. Croll's theory of the cause of glacial and interglacial climatic changes—Conclusion.

In concluding this imperfect sketch of the geology of Prehistoric Europe, it may not be out of place to present here a brief summary of the more important results arrived at. I shall also venture before I have done to make some remarks on the disappearance of Palæolithic man, and the wide interval which in Central and North-western Europe separates the close of the Old Stone Age from the beginning of the New.

We have seen that all the evidence, as well palæontological as physical, combines to prove that the Pleistocene or Quaternary Period was co-extensive with Preglacial and Glacial times. It began when the genial climatic conditions of the Pliocene were passing away, and it came to a close with the last cold epoch of the Ice Age. The fauna and flora of the Interglacial beds agree in every respect with those of the Pleistocene river-gravels, lignites, travertines, loams, and cave-accumulations. In both series of deposits the plants and animals are associated with relics of Palæolithic man, while not a trace of the latter or of the more characteristic mammals of Pleistocene times has anywhere been met with in beds of Postglacial age.

An examination of Pleistocene organic remains leads us to conclude that strongly-contrasted climatic conditions alternated during the period. At one time an extremely equable and genial climate prevailed, allowing animals, which are now relegated to widely-separated zones, to live throughout the year in one and the same latitude. Hippopotamuses, elephants, and rhinoceroses, Irish deer, horses, oxen, and bisons, then ranged from the borders of the Mediterranean as far north at least as Middle England and Northern Germany. In like manner, plants which no longer occur together — some being banished to hilly regions, while others are restricted to low grounds, and yet others have retreated to the extreme south of the Continent or to warmer regions beyond the limits of Europe—lived side by side. The fig-tree, the judas-tree, and the Canary laurel flourished in Northern France along with the sycamore, the hazel, and the willow. And we encounter in the Pleistocene deposits of various countries in Europe the same remarkable commingling of northern and southern forms—of forms that demand a humid climate and are capable of enduring considerable cold, together with species which, while seeking moist conditions, yet could not survive the cold of our present winters. The testimony of the mammals and plants is confirmed by that of the land and freshwater mollusca—all the evidence thus conspiring to demonstrate that the climate of Pleistocene Europe was, for some time at all events, remarkably equable and somewhat humid. The summers may not indeed have been warmer than they are now; the winters, however, were certainly much more genial. But if the evidence of such a climate having formerly obtained be very weighty, not less convincing are the proofs, supplied by the Pleistocene deposits, of extreme conditions. Think what must have been the state of Middle and Northern Europe when Palæolithic man hunted the reindeer in Southern France, and when the arctic willow and its congeners grew at low levels in Central Europe. Reflect upon the fact that in the very same latitude in France, where at one time the Canary laurel and the fig-tree flourished, the pine, the spruce, and northern and high-alpine mosses at another time found a congenial habitat. Bear in view, also, that the land and freshwater molluscs testify in like manner to the same strongly-contrasted climate. Besides those that tell of more equable and genial conditions than the present, there are species now restricted to the higher Alps and northern latitudes that formerly abounded in Middle Europe, and their shells occur commingled in the same deposits with remains of lemmings, marmots, reindeer, and other northern and mountain-loving animals.

It is beyond doubt, therefore, that the fauna and flora of the Pleistocene Period bear witness to great secular changes of climate. Palæolithic man lived in Europe along with many southern mammals at a time when a singularly genial and equable climate prevailed, and he was likewise a denizen of our continent when conditions altogether different obtained.

The appearances presented by the Pleistocene fluviatile deposits testify to the same prime fact—they demonstrate that the Palæolithic Period was characterised by extraordinary changes of climate. While some portions of the deposits in question bespeak the action of such streams as now drain the temperate regions of Europe—other parts indicate excessive torrential force and imply the passage of enormously-flooded rivers, and of broad sheets of inundation-water. More than this, we often encounter in the gravels large stones and blocks which could only have been transported by river-ice, and we may not unfrequently note the occurrence of confused and crumpled bedding in the same deposits, showing where the ice had packed and run aground. The ancient river-deposits that cloak the sides and bottoms of our valleys were laid down, as Mr. Prestwich has shown, while those valleys were being slowly excavated—

so that the gravels at the higher levels are the oldest, and those at the lower levels are the youngest of the series. Just as there are high- and low-level gravels, so are there high- and low-level loams. Such loams are the flood-deposits accumulated by muddy rivers from time to time, when these rose to considerable heights above their normal levels. But the great development attained by the löss-beds in many regions cannot be accounted for by ordinary river-floods. They imply the more or less sudden melting in spring and summer of enormous reservoirs of snow and ice, when water descended from the mountains and elevated regions, and filled the valleys to overflowing. And the mud deposited during such inundations we recognise as the finely-levigated sediment which is only met with in glacial rivers, or in streams which are busily engaged in washing and denuding clays and loams of glacial origin. Now löss or lehm occurs both upon valley-slopes and upon table-lands that extend between the valleys. In the latter localities it is called upland- or hill-löss, and it is evident that this high-level löss must have been laid down before the valleys were excavated to their present depths. We cannot believe in the former existence of flood-waters that were sufficiently great not only to fill valleys of such a depth, but to brim over and drown wide regions beyond—covering high table-lands and rising to some height upon many hill-slopes. It is evident, then, that the upland-löss must date back to the earlier stages of the Pleistocene Period, and we thus learn that even in those earlier times the rivers were occasionally subject to floods of enormous magnitude. But long after the valleys had been greatly deepened by river-erosion floods continued to take place, and we know that after the streams had succeeded in excavating their channels to nearly their present depth, and when the valleys had assumed pretty much the appearance which they now show, a final epoch of great inundations succeeded. To these concluding floods of the Pleistocene Period we attribute the formation of the greater portion of the valley-löss. The Rhine, the Danube, the Seine, the Garonne, and many other rivers then poured immense volumes of water down their valleys, but great as the floods were they did not as a rule succeed in filling the valleys to overflowing.

Thus the evidence supplied by the river- and flood-deposits is in perfect keeping with the testimony of the organic remains. We find the valley-slopes coated in some places with considerable accumulations of calcareous tufa, charged with leaves of such plants as the laurel, the fig, the sycamore, the ash, the willow, etc., and many land-shells, and indicating doubtless a prolonged period of repose, when the rivers flowed with an equable volume, and were not subject to excessive floods. And we read the same tale of quiet and orderly conditions in the finely-bedded deposits of gravel and sand which form no inconsiderable portion of the Pleistocene river-accumulations. On the other hand, the tumultuous coarse gravels, with their disturbed bedding and ice-floated erratics, betoken turbulent waters and river-ice, and the gradual melting of interbedded masses of frozen snow, while the thick and widely-spread loams tell us of enormous floods and inundations. And these latter excessive conditions supervened certainly more than once. The hill-löss shows that they occurred in early Pleistocene times, and the position of the valley-löss proves that the closing scene of the Pleistocene Period was one of torrential rivers and vast inundations.

The cave-accumulations indicate in like manner the recurrence during the Pleistocene Period of cold climatic conditions and flooded rivers, which alternated with prolonged epochs of repose. And they likewise show that the Pleistocene Period came to a close with severe conditions of climate. This is indicated not only by the character of the organic remains, which are met with in the uppermost layer or layers, but by the occurrence in certain caves of glacial and fluvio-glacial deposits, underneath which the Pleistocene ossiferous deposits are buried, as in the Victoria Cave in Yorkshire, and many of the Belgian caves. I believe also that the coarse breccia and the numerous large limestone-blocks which overlie the Pleistocene fossiliferous strata in many caves, owe their origin in chief measure to the action of severe frost, and pertain for the most part to the close of the Pleistocene.

We come, then, to the conclusion that the alluvial and cave-deposits of the Pleistocene were accumulated during a prolonged period, when the climate of Europe experienced several great changes, and when the fauna and the flora were compelled to perform secular migrations. Now, a close analysis of the glacial deposits of the mountainous regions and northern latitudes of Europe demonstrates that the Ice Age was not one long continuous period of arctic conditions. It was interrupted several times—how often we cannot yet say—by Interglacial epochs of mild and genial conditions, during which the central and north-western areas were occupied by the same fauna and flora which we meet with in the river- and cave-accumulations. And the conclusion is forced upon us that the so-called Glacial Period, with its alternations of severe arctic climate and mild and genial conditions, is one and the same with the Pleistocene Period. We cannot escape from this result — it follows as a logical induction from indisputable and demonstrable facts. Let us take, for example, the relation of the valley-löss to the Pleistocene river-gravels on the one hand, and the later glacial deposits on the other. We have seen that everywhere this löss overlies, and is therefore of more recent date than the younger valley-gravels. It is characterised by the presence of molluscs which imply cold and wet conditions, and of mammals of high-alpine and northern habitats. In it and underneath it we obtain relics and remains of Palæolithic man, while not a trace of these, or of any of the southern mammals with which the men of the Old Stone Age were contemporaneous, occurs upon its surface or in the later accumulations of peat and alluvium which rest upon it. The valley-löss, then, is the youngest alluvial deposit of Pleistocene age. But nothing can be more certain than this, that it is also the latest fluvio-glacial accumulation of the Glacial period. It is the loam carried down by the enormously flooded rivers of the last cold epoch of the Ice Age.

The remarkable distribution of the ossiferous and Palæolithic river-deposits might alone suffice to convince us that these cannot belong to postglacial times, as some English geologists have maintained. They occur as superficial deposits only in those regions which were not subjected to glacial abrasion, or covered with glacial accumulations during the latest phase of the Ice Age. They are either entirely absent or very meagrely developed in areas which were overflowed by the ice of the last cold epoch; and when they do occur in such regions they are invariably buried under glacial or fluvio-glacial detritus. In short, the Pleistocene river-gravels of France and Southern England are represented by the Interglacial beds of alpine and northern regions. The same fauna and flora characterise both series, and the physical evidence proves to demonstration that they must be contemporaneous. To whatever part of Europe we turn, we find that the youngest Pleistocene deposits, with their mammalian remains and relics of Palæolithic man, give token of cold climatic conditions having supervened towards the close of the period. In northern and alpine regions they are covered with morainic materials; in the greater river-valleys they lie concealed below sheets of flood-loam; in many caves they are overlaid with similar loam, or with a coarse breccia, which is indicative of severe frost. Even in the more southern latitudes they often lie buried under thick heaps of frost-riven *débris*, which no longer accumulates, but on the contrary is wasting away under present climatic conditions, while in no part of Europe do Pleistocene deposits ever rest upon the glacial, fluvio-glacial, and subaerial accumulations of the latest glacial epoch.[1]

Although Palæolithic implements have been discovered at Brandon, under the great chalky boulder-clay of East Anglia, they have not yet been chronicled from the preglacial deposits of England. Thus, we are assured that Palæolithic man lived in our area before the climax of the Glacial Period, when the northern *mer de glace* assumed its greatest development, but we do not know whether he appeared here before the advent of the first glacial epoch — that, namely, during which the Cromer boulder-clay was deposited. In France, however, implements have been detected in the sand-deposits at St. Prest, which are variously assigned to late Pliocene and early Pleistocene, but are probably of the latter or preglacial age. It is reasonable, therefore, to conclude that Palæolithic man may have entered Europe before the genial climate of the Pliocene Period had quite passed away. But whether that be so or not, he was certainly an occupant of our continent in early Interglacial times, and he survived all the subsequent climatic and geographical changes of the Ice Age, to disappear during the final phase of that period. That man must date back to a yet earlier epoch than the close of Pliocene times, few will venture to doubt, whether or not they call in question the evidence which Professor Capellini has adduced. Nor can we allow much weight to the *à priori* argument against the existence of our race in the still more distant Miocene Period. If the implements of Thenay be of artificial origin, it is more reasonable to conclude that they were fashioned by the hand of man than by a hypothetical man-ape, as M. Mortillet has suggested. But as M. de Quatrefages has said, geologists can well afford to wait for further evidence; and those savants who maintain the human origin of the Thenay implements will, I feel sure, bear with others who still hesitate to follow them with that confidence which more plentiful and less equivocal data would supply.

I come now to discuss a question which has already engaged the anxious attention of many eminent archæologists and anthropologists. We have seen that during the last glacial epoch Palæolithic man retreated south with the reindeer and its congeners, and occupied the valleys of Southern France. What is his subsequent history? Did he return northwards with the arctic and alpine animals to re-occupy the Belgian and English caves in Postglacial times? As a matter of fact, he did not. Or, to speak more exactly, we know that the tribes who occupied North-western and Central Europe after the disappearance of arctic conditions did not use the Palæolithic types of implements, and were no draughtsmen like the reindeer-hunters of Périgord. It is open, of course, to argue that the Neolithic race or races were identical with the Palæolithic tribes, who had somehow acquired a knowledge of husbandry, spinning, and pottery; who had learned to domesticate certain animals, and to finish their implements more perfectly, while at the same time they had lost the art of freehand drawing. All this is possible, but, on the other hand, it is so extremely improbable that until some positive evidence in favour of such a view be advanced we may well leave it out of account. I repeat, then, that not a vestige or trace of the Palæolithic-implement-using race occurs in any of those deposits which were accumulated in Central and Northwestern Europe in Late Glacial and Postglacial times. The men who entered Northern Italy, Switzerland, Germany, Belgium, Northern France, the British area, and Scandinavia, after the great glaciers had retreated and the rivers had returned to their normal condition, were in many ways farther advanced in civilisation than their predecessors of Palæolithic times; so great, indeed, is the difference between the conditions of life that obtained in the two Ages of Stone that we can hardly doubt that the two peoples came of different stocks. What fate, then, overtook the artistic reindeer-hunters of Périgord? At present we cannot tell. All that can be said upon the subject is only more or less plausible conjecture. Some hold that they probably migrated northwards with the reindeer, and retired to Arctic regions, where, according to Professor Dawkins, they are represented by the Eskimo. Referring to the well-known fact that a hard-and-fast line of demarcation separates the Neolithic from the Palæolithic Age in every country where their relics occur, Mr. Dawkins remarks that this would not have been the case had the Palæolithic race or races been absorbed by Neolithic invaders. "How, then," he asks, "can we account for their disappearance? Simply by assuming that at the close of the Pleistocene Age, when they came into contact with Neolithic invaders, there were the same feelings between them as existed in Hearne's times between the Eskimos and the Red Indian, terror and defenceless hatred being, on the one side, met by ruthless extermination on the other. In this way the Cave-men would be gradually driven from Europe without leaving any mark on the succeeding peoples either in blood or in manners and customs." This is certainly a simple assumption, so much so, indeed, that I fear Mr. Dawkins must have made it without due consideration; for, even granting that Palæolithic man was scared out of Europe by the terrible apparition of Neolithic invaders, are we to suppose that this had the same effect upon the fauna and flora? Did reindeer, musk-sheep, mammoth, hyæna, and cave-bear at once vanish from the scene, and a temperate flora, replacing the arctic willows and dwarf birches, spring up as if by magic in the low grounds of Central and North-western Europe?

The same writer, as I have mentioned, identifies the Eskimo with Palæolithic man, and certainly there are several points in which the living northern race resembles the ancient inhabitants of Pleistocene France. I here quote Mr. Dawkins's own summing-up of the evidence upon which he founds :—"The identity of four of the harpoons, of fowling-spears, marrow-spoons, and scrapers; the habit of sculpturing animals on their implements; the absence of pottery; the same method of crushing the bones of the animals slain in hunting, and their accumulation in one spot; the carelessness about the remains of their dead relatives; the fact that the food consisted chiefly of reindeer, varied with the flesh of other animals, such as the musk-sheep; and especially the small stature, as proved in the people of the Dordogne caverns, by the small-handled dagger figured by MM. Lartet and Christy. . . . This combination of characters is found, so far as I know, among no other people on the face of the earth except the Esquimaux; and therefore I cannot help believing that this people in South Gaul occupies the same relation to the Esquimaux, as the musk-sheep and the reindeer, on which they lived, hold to those now living in the northern regions."[1] This correlation is both ingenious and plausible, but it will hardly stand a close analysis. It comes mainly to this, that rude savage peoples living under similar cold climatic conditions and associated with the same animals will necessarily support life in much the same way. Their implements will be few and simple, and the form of such implements as harpoons, spears, marrow-spoons, and scrapers, hardly admits of much variety. If certain Eskimo harpoons are identical with some of Palæolithic age, the coincidence is not startling. The habit of sculpturing animals, etc., upon their implements is certainly remarkable, but what else have they to engrave upon? And the art of drawing figures is not confined to the Eskimo among rude unsophisticated tribes. The small-handled dagger referred to by Mr. Dawkins does not seem to prove much. If many such had been discovered this might have induced a belief that the people who fashioned them were of diminutive size; but one specimen only seems too slight a foundation upon which to build such a theory. The weapon in question may have been fashioned for or by a young lad, or it may have been merely an ornamental weapon, intended more for show than use. The other points of agreement mentioned by Mr. Dawkins, namely absence of pottery, crushing of bones, and accumulation of the *débris*, are neither strange nor unexpected. It would be difficult to make and still more difficult to preserve coarse pottery in an arctic climate, and I have sometimes thought that this may be partly the reason why potsherds seem to be wanting in the accumulations of the so-called Reindeer period. As for the crushing of bones and the heaping up of the *débris*, these are practices not peculiar to the Eskimo among modern savages, nor were they confined to Palæolithic man amongst the prehistoric races of Europe. Lastly, the Eskimo may be careless enough about their dead relatives, but there is no proof that such was the case with the Palæo-

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[1] See *Quart. Journ. Geol. Soc.*, vol. xxiii. p. 183. More recently Mr. Dawkins has insisted upon the striking resemblance of certain perforated implements (see *supra*, p. 14) to the "arrow-straightener" of the Eskimo. But the close similarity to which he has drawn attention one may readily admit without feeling constrained to conclude that the Palæolithic and modern implements in question

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have been fashioned by one and the same race. Were such isolated and unimportant correspondences to guide us in classifying living races, we might find ourselves establishing ethnical affinities between peoples who really belong to the most diverse stocks.

lithic people, as I have already shown. I do not think, therefore, that the identification of the Eskimo with the reindeer-hunters of Périgord can be sustained by such considerations as those advanced by Professor Dawkins. The resemblances pointed out by him appear to be only coincidences, which, either singly or combined, have no such special significance as he supposes. I do not of course deny that the Eskimo may be related by descent to Palæolithic man. But we cannot be expected to accept the evidence relied upon by Professor Dawkins unless it be supported by the testimony of the human skull itself. When anthropologists produce from some of the caves occupied by the reindeer-hunters a cranium resembling that of the living Eskimo, it will be time enough to admit that the latter has descended from the former. But, unfortunately for the view here referred to, none of the skulls hitherto found affords it any support. It is true that Professor Dawkins would explain away their testimony, but against his opinion we must set that of those high authorities—MM. Hamy and Quatrefages—and leave the anthropologists to settle the question amongst themselves. I have here to do not with anthropological but geological evidence, and certainly this latter seems to furnish strong grounds for setting aside the conclusion that Palæolithic man retreated northward to the Arctic regions. Let us picture to ourselves the climatic and physical conditions that obtained towards the close of the last glacial epoch. We see the snow-fields gradually diminishing in extent—the glaciers slowly retiring—and floods and inundations decreasing in magnitude. The northern and alpine flora is again advancing northwards, followed by those mammals which are now restricted to lofty elevations and high latitudes. There was, in short, no sudden change from the extreme conditions of the Glacial Period to the temperate climate which supervened in Postglacial times. Animals and plants, no doubt, emigrated northwards just as slowly and continuously as they had previously migrated southwards during the approach of the latest cold epoch of the Ice Age. We know that the reindeer and its associates returned to their old haunts in the north; and we meet with their remains not only in the late glacial deposits but in the postglacial alluvia and peat of Central and North-western Europe. But in these deposits they are never accompanied by the relics of Palæolithic man. If we take a map of Europe and colour accurately all those areas over which are spread the deposits of the last glacial epoch—the upper boulder-clay, the morainic *débris,* diluvial gravel and sand, löss and lehm, and subaerial angular drift—we shall find that the coloured part represents regions in which the relics and remains of Palæolithic man are entirely wanting in all superficial accumulations of alluvia and peat. The conclusion, therefore, seems inevitable that whithersoever the reindeer-hunters of Périgord may have retreated, it could not have been northward through the regions which they occupied during Interglacial times. Nor can we escape from this conclusion by pleading that Palæolithic relics may yet be detected in postglacial accumulations. It is true that our knowledge of these accumulations, although abundant, is not exhaustive, but had Palæolithic man emigrated northwards we should certainly long ere this have discovered some notable proof of that northward migration in the many deposits which have already been examined. The conspicuous fact that none such are forthcoming, although they have been sedulously searched for, must be taken in the present state of our knowledge as proof that the men of the Reindeer period did not return with the gradually-retreating northern forms.

Other writers are of opinion that the man of the Reindeer period in Southern France probably remained where he was, to become absorbed in the new wave of population that swept into Europe at the close of the Glacial Period. If this were so, then we should expect to find no gap or hiatus in Périgord and the Pyrenean regions between Palæolithic and Neolithic times; but in the caves of those districts the same line of demarcation—so striking in the caves of Belgium, England, and elsewhere—separates the accumulations of the two periods. There are certain appearances, however, met with in some Pyrenean caves, as in that of Gourdan, described by M. Piette, which lead to the suspicion that the interval between the Palæolithic and Neolithic Ages in Southern France may not have been prolonged, that the former may have merged somewhat suddenly with the latter. This is the view which M. de Quatrefages among others inclines to support, basing his opinion upon anthropological considerations. He lays considerable stress upon the results obtained by MM. Lartet and Duparc in their examinations of the rock-shelter of Sorde in the Department of the Basses-Pyrénées, where a superficial stratum with Neolithic relics was found resting upon a Palæolithic accumulation, with the upper portion of which it was partly confounded. In the lower part of the Palæolithic beds a human skull and bones were found, together with a necklace of the teeth of the lion and bear, while in the upper portion, which consisted largely of charcoal, many Palæolithic implements and barbed arrows of the "Magdalenian type" were detected. Mixed with these were bones of ox, horse, and reindeer—the latter being rarer than the others. In the overlying Neolithic layer, composed chiefly of human bones, were obtained several worked flints resembling those of the beds below, and a triangular dagger of unmistakable Neolithic workmanship. Now the human remains of both levels are referred by M. Hamy, with whom M. de Quatrefages quite agrees, to one and the same race of people—to that, namely, which is designated by them the "Cro-Magnon race"—of which the types are the skulls of an old man and a woman that were obtained along with many remains of the Pleistocene mammalia from a cave at Les Eyzies on the banks of the Vezère. "Is it not evident," asks Quatrefages, "that this race must have known both the latest times of the Reindeer age, and the earliest of the present epoch?" He and his collaborateur M. Hamy, indeed, recognise the Cro-Magnon type in human remains which have come from many other Neolithic stations, and not only so but even in races still living, as for example in the Kabyles of the Beni Massar and the Djurjura of North-western Africa. It is, however, more especially in the Canary Islands and Teneriffe, where M. Hamy has met with skulls, "the ethnical relation of which with the old man of Cro-Magnon is beyond discussion. On the other hand, some points of comparison, unfortunately very few in number, have led him to regard the Dalecarlians (Sweden) as connected with the same stock. . . . They (the reindeer-hunters of Périgord) were perhaps only a branch of an African population which had emigrated to France with the hyæna, the lion, the hippopotamus, etc. In this case there is no difficulty in explaining its existence at the present day in the north-west of Africa, and in the islands, where it would be protected from crossing. Some of its tribes carried away in the pursuit of the reindeer will have preserved in the Scandinavian Alps the tall form, the dark hair, and brown complexion which distinguish Dalecarlians from the neighbouring populations; others, mixing with all the races by which France has been successively invaded, only betray their ancient existence by the phenomena of atavism, which lays upon some individuals the mark of the old hunters of Périgord."[1] On a question such as that which MM. Quatrefages and Hamy discuss—the racial characters of Palæolithic and Neolithic remains—I have no title to express an opinion. I can only say that so far as the geological evidence goes, it seems to favour to some extent their general conclusion. It is quite clear that a wide interval separates the Palæolithic and the Neolithic Ages everywhere in Central and North-western Europe; but it is less certain that this interval was as prolonged in the south of France. Possibly, therefore, the Palæolithic and the Neolithic races may have commingled in Périgord at a time when the reindeer was still living, but in greatly diminished numbers, in the valleys of the Pyrenees. But there is nothing to show that any of the Palæolithic tribes were "carried away in the pursuit of the reindeer" to its present home in Scandinavia. A prolonged period intervened between the close of the Ice Age and the reappearance of man in Central and North-western Europe. Glacial conditions had vanished, and the arctic and alpine forms had retired to their present limits before the territories vacated by Palæolithic man upon his final retreat to Southern France came to be occupied by his Neolithic successor. In late glacial and early postglacial times Central and North-western Europe were, so far as we know, untenanted by man. It is conceivable, however, that long after the main body of the northern mammals had retired from Southern France, the reindeer and some of its congeners may have continued along with Palæolithic man to occupy the valleys of the Pyrenees. As the climate improved, and the reindeer became scarce and eventually died out, the Palæolithic people would probably accommodate themselves to the gradually changing conditions, and this may have been the state of matters when the first wave of Neolithic population swept round the flanks of the Pyrenees, and overflowed upon the low ground—thus effectually cutting off the retreat of the older race. Whether this was what actually happened future investigations must be left to determine. At present all we know is that in not a few caves of the Pyrenees, as Dr. Garrigou has shown, the line of demarcation between Palæolithic and Neolithic deposits is quite as well marked as in the caverns of North-western Europe. In others, however, the separation is by no means so clear, and may indicate, as M. Piette has maintained, that the older and newer races came into more or less violent contact; the unconformity or discordance in the cases referred to by Dr. Garrigou being accounted for on the supposition that those caves had been abandoned by Palæolithic man long before the advent of his Neolithic assailant.

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[1] De Quatrefages, *The Human Species*, p. 335.

To the last glacial epoch of the Pleistocene Period there gradually succeeded genial climatic conditions—somewhat analogous to those of Interglacial ages. Britain and the southern portion of the Scandinavian peninsula, which towards the close of the Glacial Period had experienced considerable submergence, were now gradually re-elevated, and by and by dry land joined our islands to themselves and the Continent. Arctic and alpine plants and animals had now retired to high latitudes and mountain-elevations, while the great Germanic flora had established itself in all the temperate regions of Europe. Dense forests extended far north into countries which are now desolate and bare, and reached to altitudes in our mountain-regions at which trees will no longer grow. At this period Spitzbergen, Greenland, Iceland, and the Færöe Islands had land-connection with our continent, as is proved by the character of their floras, and by the fact that those floras could only have immigrated in postglacial times.

Clothed with an abundant vegetation, stocked with vast herds of oxen, deer, and other forms characteristic of the temperate zone, the Europe of this genial Postglacial epoch approached in character to that of Interglacial times. The southern mammals, however, did not revisit their old haunts—hippopotamuses, elephants, and rhinoceroses were unknown in Postglacial Europe. Even the southern carnivores—the hyænas and servals—never returned. The land-bridges which had formerly connected our continent with Africa had disappeared, and thus the re-advance of the southern forms was effectually prevented. No such obstacle, however, could stay the migrations of marine life-forms. The warm ocean-currents flowing from the south in larger volume than now brought with them many immigrants to people our northern seas, where the conditions in our own day no longer favour their increase and dispersion. Many facts thus conspire to show that the climate of these early Postglacial times was clement and equable—the strong winds which now forbid the growth of trees in high latitudes were then much less prevalent, and plants which are now relegated to different stations then flourished together in the same habitats.

Eventually a movement of depression commenced in the far north, and succeeded ere long in isolating Spitzbergen and Greenland, and in cutting off the land-connection between Europe and the Færöe Islands and Iceland. But before the reappearance of the North Sea Neolithic man had entered Europe and crossed into Britain.

The genial climate now began to pass away and to be succeeded by less clement conditions; while, at the same time, the British area was gradually insulated. Snow-fields and glaciers again reappeared in our mountain-regions, and the sea rose upon our coasts to a height of some 40 or 50 feet above its present level. At this time Neolithic man frequented our shores, and harpooned the Greenland whale in our waters. To the same, or approximately the same, period probably belong the kitchen-middens of Denmark. The great forests had already decayed in many places, and were gradually overgrown with mosses and converted into boggy wastes, while the elk and the reindeer had once more descended to the low grounds of Germany. The climate had then become cold and extremely humid—it was, in short, a relapse to a kind of modified glacial epoch.

By and by, however, another change ensued. The climate gradually recovered something of its old genial character, the local glaciers of the Scottish mountains melted away, and the forests again began to extend their bounds in temperate Europe. The boggy wastes became dry and were overgrown by trees which, in Ireland, Northern England, Scotland, and Scandinavia appear to have been principally pine. At this period the sea retired from our coasts, and the land in North-western Europe attained a somewhat greater extent.

As years rolled on, yet another change took place. The climate of North-western Europe again became more humid, and the conditions less suited to the growth of great forests. Wide areas were by and by displenished, and peat-bogs extended themselves over the prostrate trees. At the same period the sea advanced upon the shores of Britain to some 20 or 30 feet, and upon those of Scania to 10 or 15 feet above its present limits. It was during this second humid or peat-accumulating epoch that the use of bronze became known to the tribes occupying Britain. The introduction of iron followed, geologically speaking, very shortly afterwards. Thus the disappearance of humid conditions and the retreat of the sea to its present level appear to have taken place during the so-called Age of Iron.

The changes effected by the hand of man do not come within the scope of this inquiry, nor do I take cognisance of the many modifications which have been produced by recent volcanic action, the denuding force of waves and currents, and the growth of deltas upon the outline of the land within historical times. All these have conspired to bring about the present climatic and geographical conditions of our continent; and to so great an extent is this the case, that it is often extremely hard, or even impossible, to assign to each factor its proper share in the result produced. At present we seem to be living in a comparatively dry epoch—but the appearances that lead to this conclusion are not improbably due in no small measure to the drainage-operations of the husbandman.

It will be noted that our knowledge of postglacial climatic changes is derived chiefly from an examination of the postglacial accumulations of North-western Europe. This arises from the circumstance that such mutations must necessarily have been most marked in the higher latitudes. Farther to the south they would become less and less appreciable, just as in Pleistocene times the contrast between glacial and interglacial conditions must have been less pronounced in southern than in northern regions.

Hitherto I have said nothing as to the absolute duration of the Pleistocene and the Postglacial Periods. The phenomena described leave us in no doubt that an immense lapse of time intervened between the appearance and disappearance of Palæolithic man, and the changes which took place during the Postglacial Period likewise demand considerable time for their evolution. Within recent years several attempts have been made to estimate the dates of the Neolithic and later Ages, and the results obtained are interesting and suggestive. Thus, M. Morlot has shown that the cone of alluvium and detritus brought down by the torrent of the Tinière to the Lake of Geneva at Villeneuve, and of which an admirable section was exposed in the railway-cutting, exhibits three distinct and superposed layers of vegetable soil or old land-surfaces, which are separated from each other by a variable depth of detritus. The uppermost layer contained tiles and a Roman coin; in the second were found fragments of unglazed pottery, and a pair of bronze tweezers, while the third afforded relics which are assigned to the Neolithic period. Assuming the Roman layer to have an antiquity of 1600 years, M. Morlot obtains for the Bronze Period an age of 3800 years, and for the Neolithic period 6400 years, or, in round numbers, 3000 to 4000 years for the former, and 5000 to 7000 years for the latter. Again, Professor Gilliéron has endeavoured to compute the time required for silting up the valley of the Thièle, up which the Lake of Bienne formerly extended to the Pont de Thièle, where an ancient lake-dwelling has been discovered. Calculating that the lake has retired from the valley for some 375 mètres since the Abbey of St. Jean was founded about 750 years ago, he concludes that 6750 years at least have elapsed since the lake reached the spot where the pile-building occurs. With these conclusions of MM. Morlot and Gilliéron, the results obtained by M. H. de Ferry in the valley of the Saône, between Tournus and Mâcon, agree sufficiently well, the age assigned by him to certain Neolithic accumulations being not less than 4383 years.

Interesting and suggestive as these computations undoubtedly are, they yet do not enable us to form any approximation to the date of the commencement of the Neolithic Period. Even if we assume them to be more exact than their authors claim them to be, still they tell us no more than that Neolithic man was living in Europe some 5000 or 7000 years ago. It may well be that the Neolithic phase of civilisation survived down to that time, but the ancient submerged peat-bogs and submarine forests with their Neolithic relics can hardly be assigned to so recent a period. The great geographical and climatic mutations, and the consequent modifications of fauna and flora which took place in Postglacial times, demand, as it seems to me, a much longer time for their accomplishment. But any term of years I might suggest would be a mere guess; I have written to little purpose, however, if the phenomena described in preceding chapters have failed to leave the impression upon the reader that the advent of Neolithic man in Europe must date back far beyond fifty or seventy centuries.

Although I am not prepared to give a more or less definite date for the beginning of the Later Prehistoric Period, I am far from thinking that a greater definiteness will not some day be attained. All the chronometers which have hitherto been appealed to by geologists are somewhat misleading, for we cannot assume that peat, alluvia, and other strata, have attained their present thickness at the same rate as they are now accreting. The climatic changes of the past must likewise be taken into our calculations, and the precise effect of these it will always be a hard matter to compute. But until this is done our results must be inadequate and incomplete. Whilst readily admitting that the methods employed by Morlot and others are of the greatest value, and have given a precision to our conceptions of the antiquity of archæological periods, which was previously wanting, I confess that it is rather to the astronomer and the physicist than to the geologist that I look for assistance in ascertaining the more precise chronology we are in search of. Continued study of Glacial and Postglacial deposits has deepened my conviction that the theory advanced by my friend and colleague Dr. Croll contains the secret of the whole matter. This theory gives an adequate explanation of that great alternation of cold and genial climates which obtained during the Pleistocene or Glacial Period, and enables us to fix the date of the Ice Age with as much exactness as we can ever hope to attain. If it be true, then, that the Pleistocene era corresponded with the latest period of excessive eccentricity of the earth's orbit, it follows that the beginning of the Palæolithic Age must go back some 200,000 years ago; nor to those who are adequately acquainted with the vast changes which supervened during Glacial and Interglacial times will such an antiquity appear extravagant. On the contrary, many geologists, looking at the enormous results that accrued from the action of the denuding forces in the Pleistocene Period, have been inclined to assign even a higher date to the commencement of the Ice Age.

The closing phase of that Age was one of extreme glacial conditions; when it passed away, the Postglacial Period began. And I think it is a strong confirmation of the correctness of Dr. Croll's views that the last cold epoch of the Ice Age was succeeded by the genial climate which characterised Europe in early Postglacial times. It might have told somewhat against the validity of his theory had the great cycle of Glacial and Interglacial conditions come to a close with a period of such intense glaciation as that which distinguished the deposition of the later moraines, upper boulder-clay, and valley-löss. But it is quite in keeping with that theory that alternations of less strongly-marked genial and cold conditions should recur in Postglacial times, when the eccentricity of the earth's orbit, although diminishing, was still considerably in excess of what it is at present. Accordingly, we find that the genial period of early Postglacial times was succeeded by a relapse to colder conditions, when local glaciers again made their appearance in many mountain-valleys of Scotland. The extreme freshness of the glacial phenomena in those regions, which has often been referred to as telling against the antiquity of the Glacial Period, is thus due to the fact that they belong to Postglacial times. Whether the later changes of climate and minor oscillations of the sea-level in North-western Europe are the final effects produced by diminishing eccentricity, or whether, as Dr. Croll has suggested, they may have some connection with changes in the obliquity of the ecliptic, I must leave to be discussed at some future time. I will only say that the phenomena referred to can hardly have been produced by mere elevations and depressions of the land, but are much more likely to owe their origin to cosmical causes. Should this eventually prove to be the case, we shall thereby acquire a more exact date for the later Prehistoric Ages than we are ever likely to obtain by any of the various ingenious methods of computation which have been devised by geologists.

Thus, although I have drawn a line of demarcation between the Pleistocene and the Postglacial periods, they must yet be looked upon as parts of one and the same great cycle. We note, as we advance from Pliocene times, how the climatic conditions of the colder epochs of the Glacial Period increase in severity until they culminate with the appearance of that great northern *mer de glace* which overwhelmed all Northern Europe, and reached as far south as the 50th parallel of latitude in Saxony. Thereafter the glacial epochs decline in importance until in the Postglacial period they cease to return. The genial climate of Interglacial ages probably also attained a maximum towards the middle of the Pleistocene Period, and afterwards became less genial at successive stages, the temperate and equable conditions of early Postglacial times being probably the latest manifestation of the Interglacial phase. The Ice Age, therefore, cannot be considered as a prolonged and uninterrupted period of glaciation, separating, as by an impassable barrier, one geological horizon from another. Ever and anon the characteristic glacial conditions vanished, and a mild and genial climate succeeded, thus giving rise, again and again, to great migrations and numerous extinctions and modifications of species, and to the present peculiar distribution of fauna and flora. It was probably by similar means that species were dispersed and modified at much more distant epochs in the world's history; and if it be true that the greater changes of climate of which this volume treats were brought about by astronomical and physical causes, then we cannot doubt that the same causes must have been in operation at different and widely separated periods in the past. Already many indications that such was the case have been noted, and more particularly, as might have been expected, in the Tertiary formations. Within the past few years the late Signor Gastaldi's view that the great erratics of the Miocene of the Moncalieri-Valenza hills, near Turin, are of glacial origin, has been extended to various other regions of Europe;[1] and that such observations will continue to multiply as our knowledge increases may be confidently expected. Nor is it a too sanguine hope that the time will yet come when geologists shall attempt to measure off the æons of the past, and assign to each formation its approximate antiquity. Guided by the astronomer and the physicist, they may yet penetrate mysteries which at present appear inscrutable, and be enabled to follow with a clearer and steadier gaze the working of the Divine Creator in ages so remote that, compared with them, the Glacial Period of which I have been speaking seems of no earlier date than yesterday.

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[1] See Jules Martins: *Bull. Soc. Géol. France*, 2e Sér. t. xix. pp. 153, 450; 3e Sér. t. i. p. 390; t. ii. p. 269; *Observations sur divers produits d'origine glaciaire en Bourgogne*, Paris, 1873. The phenomena described by M. Martins have been otherwise explained by M. Delafond (*Bull. Soc. Géol. France*, 3e Sér. t. iv.

p. 665); M. Arcelin (Les formations tertiaires et quaternaires des environs de Mâcon, *Ann. de l'Acad. de Mâcon*, 1877); and M. A. Falsan (*Note sur l'origine de l'argile a silex des environs de Mâcon et de Chalon*, 1878). For further notices of Tertiary erratic or boulder formations, see Stuart Menteath, *Bull. Soc. Géol. France*, 2e Sér. t. xxv. p. 695; Collomb, *Ibid.*, t. xxvii. p. 559; Tardy, *Ibid.*, t. xxix. pp. 541, 547; 3e Sér. t. iv. p. 184; Roujou, *Congrès intern. d'Anthrop. et d'Archéol. Préh.* (1871) p. 86; R. v. Drasche, *Jahrb. der k.-k. geol. Reichsanst.*, Bd. xxix. p. 112; Mantovini, *Boll. Com. Geol. Italia*, 1878, p. 443.

APPENDIX.

NOTE A.

TABLE OF SEDIMENTARY FORMATIONS.

1.	Recent	POST-TERTIARY.	TERTIARY OR CAINOZOIC.
2.	Postglacial		
3.	Pleistocene or Quaternary (includes Glacial formation)		
4.	Newer Pliocene	PLIOCENE.	
5.	Older Pliocene		
6.	Upper Miocene	MIOCENE.	
7.	Lower Miocene (includes most of Brown Coal formation of Germany = Oligocene of Beyrich)		
8.	Upper Eocene	EOCENE.	
9.	Middle Eocene		
10.	Lower Eocene		
11.	Maestricht Beds and Faxö Chalk	CRETACEOUS.	SECONDARY OR MESOZOIC.
12.	White Chalk		
13.	Chloritic Series		
14.	Gault		
15.	Neocomian		
16.	Wealden		
17.	Purbeck Beds	JURASSIC.	
18.	Portland Stone		
19.	Kimeridge Clay		
20.	Coral Rag		
21.	Oxford Clay		
22.	Inferior Oolite		
23.	Lias		
24.	Rhætic or Penarth Beds	TRIASSIC.	
25.	Keuper		
26.	Muschelkalk		
27.	Bunter Sandstein		

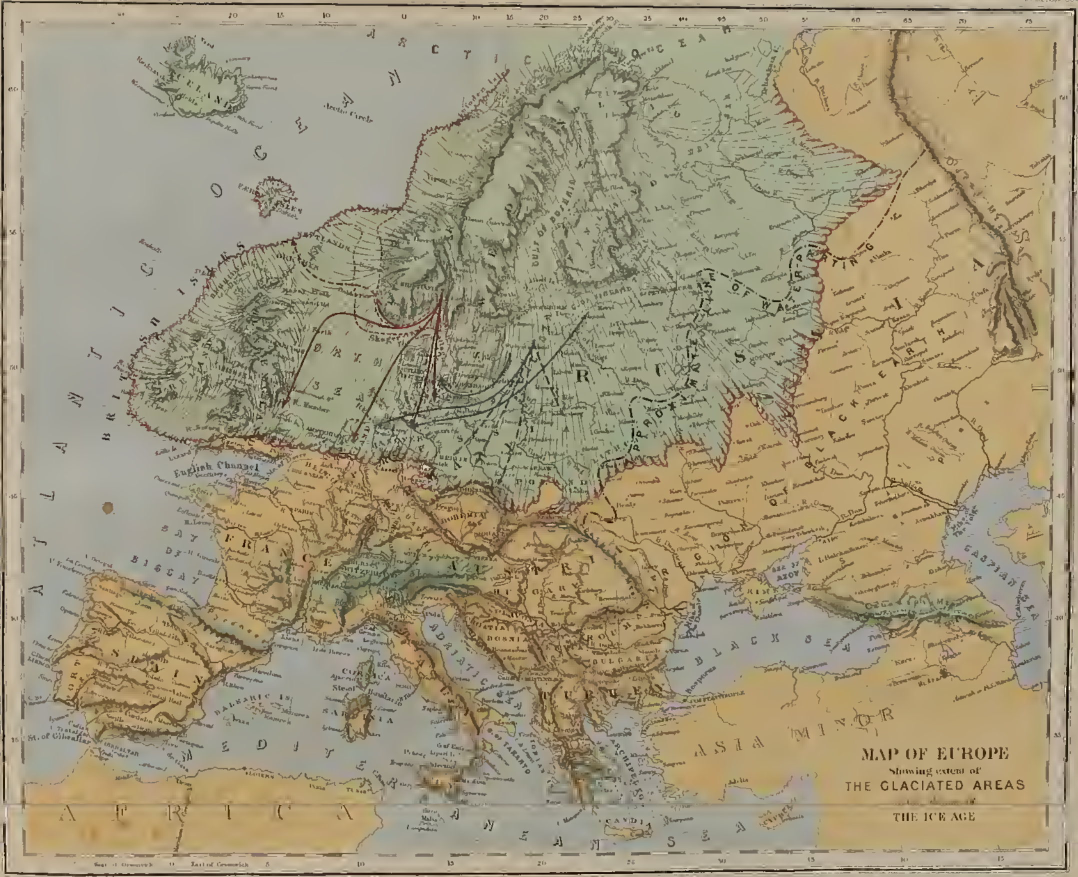
28. Permian	PERMIAN.	PRIMARY OR PALÆOZOIC.
29. Coal-measures	CARBONIFEROUS.	
30. Carboniferous Limestone		
31. Lower Limestone Shale, etc.		
32. Devonian Beds and Old Red Sandstone	DEVONIAN & OLD RED SANDSTONE.	
33. Upper Silurian	SILURIAN.	
34. Lower Silurian		
35. Cambrian	CAMBRIAN.	
36. Fundamental Gneiss	LAURENTIAN.	

Note B.

PLATE D.—Map of Europe at the Climax of the Ice Age.

This map shows the centres of local glaciation, and the area covered by the northern *mer de glace* at the climax of the Glacial Period. For the line indicating the southern limits reached by this ice-sheet I have taken the boundary of the "Northern Drift and Erratics," as defined by Murchison and his colleagues, with a few modifications adopted from the map of "Europa während der beiden Eiszeiten," by H. Habenicht (*Petermann's Geographische Mittheilungen*, 1878). The thin red lines are intended to represent the principal directions followed by the superficial strata of the *mer de glace*. These, as a rule, corresponded with the trend of the lower strata also, but now and again, owing to the form of the ground and other causes, the ice at the bottom was impelled out of the course pursued by the strata at a higher level. I have given in the text (p. 203) an example —the long red arrows that radiate from Christianiafjord being the inferred directions followed by certain erratics derived from that region.

Mention has been made of the fact that Scandinavian erratics occur in the boulder-clay of Saxony, and since this last is a true *moraine profonde*, it follows that the erratics in question must have been dragged over the bed of the Baltic and across the low grounds of Germany before they could have reached their present position. Again, at Lyck in East Prussia, at Trebnitz and Steinau in Silesia, at Meseritz in Posen, and at Berlin, we find fragments of Silurian rocks which are recognised as having come from the island of Gottland in the Baltic. All these might quite well have been rolled forward under one and the same ice-sheet, but how are we to account for the presence in the boulder-clay of Gröningen in Holland of boulders of the same rocks? It is evident that these last must have come down the basin of the Baltic and crossed the route followed by the others nearly at right angles. Nor are these cases altogether exceptional, for we learn that erratics from Esthonia have been detected in boulder-clay at Hamburg, and that fragments derived from the island of Öland are met with in the till of Faxö in Denmark. The probable routes followed by these erratics are indicated by the long continuous blue


ARCTIC OCEAN
ATLANTIC OCEAN
ICELAND
Arctic Circle
FAROE ISLES
BRITISH ISLES
NORTH SEA
Skagerack
GULF OF BOTHNIA
RUSSIA
LINE OF WATER PARTING
English Channel
BAY OF BISCAY
FRANCE
SWITZERLAND
BOHEMIA
AUSTRIA
HUNGARY
BOSNIA
ROUMANIA
BULGARIA
TURKEY
SPAIN
PORTUGAL
BALEARIC IS.
CORSICA
SARDINIA
ADRIATIC SEA
St. of Gibraltar
MEDITERRANEAN SEA
CANDIA
BLACK SEA
SEA OF AZOV
CRIMEA
CASPIAN SEA
ASIA MINOR
AFRICA

MAP OF EUROPE
Showing extent of
THE GLACIATED AREAS
[illegible]
THE ICE AGE

London: Edward Stanford, 55, Charing Cross, S.W.

arrows, while the interrupted blue arrows show the course taken by the Gottland boulders that went to south-east and south. It is hardly possible that all these erratics could have been transported by one and the same ice-flow ; they are more likely, as Mr. Helland has remarked, to have travelled at different times. When the *mer de glace* attained its maximum development we know that it reached down to Silesia and Saxony, and at that time the stones carried forward with the *moraine profonde* from the Baltic provinces of Russia would spread towards S.E., S., and S.S.W. In like manner boulders from Gottland would have a tendency to move to S.S.E., S., and S.W. But when the *mer de glace* had become much reduced, and no longer flowed so far south, the lower strata of the ice in the Baltic would be to a great extent confined to that hollow, and hence the bottom-moraine would tend to be pressed and rolled forward down the trough towards the Kattegat and the North Sea. In this manner fragments detached from the rocks of Esthonia and the islands in the Baltic might well come to be scattered through the drift deposits of Hamburg, Gröningen, and Denmark. And that this is not a mere unsupported conjecture is shown by the fact that the striæ in Gottland, in the southern extremity of Sweden, and in Zealand, clearly evince that the ice has flowed in different directions. Thus in Gottland most of the striæ point to S.W., but another set of glacial groovings goes towards S. and S.S.E. In the south of Sweden, again, while one series of striæ indicates a glaciation in an approximately southern direction, another set proves an ice-flow towards S.W. At Faxö the direction varies from N.W. to W. and S.W.

But even at the period of maximum glaciation, considerable oscillations in the direction of the *mer de glace* may have been induced by variations in the thickness of the ice itself. If the precipitation of snow were to become abnormally great in some particular region, so as to give rise to a local thickening of the ice-sheet, this of itself would tend to modify the direction of the ice-flow, and so bring about a corresponding modification in the trend of the stones and rubbish travelling forward at the bottom. And such local changes, being repeated at different times and in different areas, might eventually give rise to some of the cases of abnormal distribution of erratic blocks referred to above. But oscillations of this kind are not required to account for the fact that rock-fragments, detached from some particular district of small extent, are often distributed over a very much wider area to the south. A glance at the map will show that the *mer de glace*, as it flowed on towards its terminal line, gradually spread itself over a wider and wider area. And this being so, the same must have been the case with its bottom-moraine. It is not surprising, therefore, that stones derived from Gottland should have been distributed by one and the same ice-sheet over a considerable area to S., S.W., and S.E. of that island.

There is yet another cause which may have played no unimportant part in the distribution of erratics under the ice-sheet. I have endeavoured to show (see page 239) that subglacial rivers must have existed, and that these in Northern Germany would follow the general slope of the land, and would thus often flow in directions opposed to the course of the *mer de glace*. We can hardly doubt that quantities of morainic *débris* would find their way into such subglacial streams, and thus stones, and even boulders of some size, might come to be carried often for long distances out of the route they had followed when imprisoned in the *moraine profonde.* Indeed, it is quite possible that now and then portions of the ice itself, charged with rock-fragments, might fall into subglacial waters and travel many miles in the most contrary directions. We have now only further to conceive some change taking place in the course of the subglacial channels—caused probably by modifications in the ice-flow overhead—when the bed of the subglacial river would be invaded and its detritus become commingled with the unmodified drift or boulder-clay of the *moraine profonde.* In this manner erratics from widely-separated districts might occasionally become mixed up in one and the same subglacial accumulation.

But the most potent cause of all remains to be mentioned. It has been shown that the direction pursued by the ice in the basin of the Baltic was different at different periods. When the *mer de glace* reached down to Saxony and Silesia, boulders and smaller stones, derived from Sweden, were dragged over the bed of the Baltic, and carried south to the farthest limits reached by the ice-flow. But when the *mer de glace* was on the wane, and had melted away over a large part of Germany, the ice in the Baltic basin followed the direction of that trough towards the southwest. Now, as we have seen, the great *mer de glace* invaded the low grounds of Germany three times at least. And these epochs of glaciation were separated by long intervals of milder conditions, during which the ice disappeared, and left the land to be reclothed and repeopled by plants and animals. With each successive advance and retreat of the ice, therefore, fresh accumulations of boulder-clay would be formed, but we cannot doubt that the *moraine profonde* would in many places consist to some extent of the rearranged morainic materials which had been left behind during the disappearance of each preceding *mer de glace.* The modifications which must have been brought about by this means are more than sufficient to account for all the abnormal cases of "erratic distribution" which have been referred to. Indeed, the wonder is that these are not more numerous than they appear to be. It is highly probable that, when the work of correlating the various boulder-clays of Germany and the adjacent regions has been worked out in detail, it will be possible to map out the area covered by the ice-sheet during each separate glacial epoch, and not only so, but to determine approximately the prevailing directions followed by the separate ice-flows. Already, indeed, it has been observed that the upper and lower boulder-clays of one and the same place often contain very different percentages of stones and boulders. Thus, according to Harting, the upper boulder-clay in the island of Urk contains only 2·2 per cent of flints, while the lower dark-gray till shows 38·5 per cent.

I have made special reference to these cases of abnormal distribution[1] of which I have been speaking, because they have been held by some as tending to prove the improbability of the boulder-clays of Northern Germany, etc., having been accumulated and distributed underneath a *mer de glace.* To me they appear to tell a very different tale, and are just such as one might have expected to meet with. In spite of these exceptions, which are comparatively rare, the distribution of the great mass of stones in the boulder-clays that occur towards the southern margin of the Northern Drift indicates that during the climax of the Ice Age, when the *mer de glace* attained its greatest development, it flowed in the general directions shown upon the map. The boulder-clays of Northern Germany, etc., like those of other countries, are composed in large measure of the *débris* of local rocks. They always, in short, reflect the character of the strata upon which, or to the immediate south of which, they lie. Moreover, commingled with *débris* of such local origin, fragments derived from greater distances to the north are invariably present, in less or greater abundance. In a word, the phenomena of the German boulder-clays are the exact counterpart of the appearances presented by the boulder-clays of Northern Italy, Switzerland, Scandinavia, Finland, and the British Islands.

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[1] Mr. Helland has given an interesting and useful summary of a number of the more remarkable examples in his very able paper descriptive of the glacial deposits of the low grounds of Northern Europe (*Zeitschr. der deutsch. geol. Ges.*, 1879, p. 63), to which, and to Dr. Penck's paper (*Op. cit.* p. 117), I would refer the reader for a much fuller discussion of the subject than I can enter upon in this place.

For the termination of the ice-sheet west of the British Islands I have taken the line of 100 fathoms, as indicated upon the Admiralty's charts, but I have followed my friend Mr. Helland in drawing the line off the west coast of Norway in deeper water.[1] Of course these boundaries are only conjectural. We cannot tell how far the ice-sheet flowed out into the Atlantic, because we do not know whether the land stood then at a lower or higher level than it does now. We may safely say, however, that with the sea at or about its present depth, the Scottish ice, which overflowed the Outer Hebrides, could hardly have reached beyond the line of 100 fathoms. But it may well be that the ice streaming out from Norway was massive enough to advance considerably farther into the bed of the Atlantic.

The direction and extent of the glaciation of the Færöe Islands were determined by Mr. Helland[2] and myself.[3] The ice which covered those islands formed one compact *nappe*, which flowed outwards in all directions, and, with the sea at its present depth, must have extended as far from the coast as the 100-fathoms line of soundings. The marks of glacial abrasion were traced up to a height of 1600 feet, and as the fiords are here and there 100 fathoms deep, we must add this to the other measurement to get the maximum thickness of the ice (2200 feet) that flowed out from the islands.

It is most likely that when the glacial phenomena of Iceland come to be better known, we shall find that this island also has supported an ice-sheet, which would flow outwards upon the bed of the sea in the same manner as the local and independent ice-cap of the Færöes. I have, however, simply coloured the area of Iceland green, like the local centres of glaciation in Central and Southern Europe.

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[1] *Zeitschr. der deutsch. geol. Ges.*, 1879, p. 716.

[2] *Op. et loc. cit.*

[3] *Proc. Royal Soc. Edin.*, 1880, p. 495.

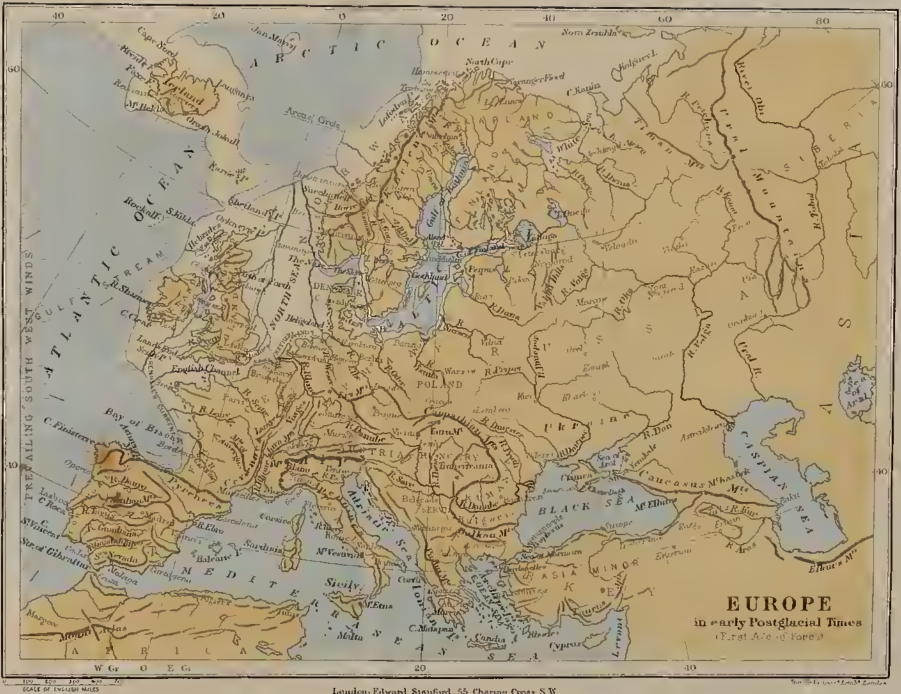
NOTE C.

PLATE E.—EUROPE IN EARLY POSTGLACIAL TIMES (FIRST AGE OF FORESTS).

THIS map shows the probable extent of land that obtained in early Postglacial times when the climate was mild and genial, and the Færöe Islands and Iceland received their floras from the European mainland. Of course the line given for the land extending from the Færöe Islands to Iceland is conjectural. The soundings upon the charts are few in number and wide apart, and, doubtless, the coast would be much more irregular than is here indicated. For the coast of the mainland from Spain to St. Kilda I have followed the line of 100 fathoms, and from St. Kilda northwards that of 500 fathoms, which is also that of the Icelandic area. I have endeavoured to show that before this great extension of land took place there had been a considerable increase in the volume of warm water flowing from the South into the Northern Ocean, accompanied by the immigration of many southern forms of life into the Norwegian Seas. An elevation of the land and consequent retreat of the sea afterwards supervened, as may be inferred from the fact that the Færöe Islands, Iceland, and even Greenland, have received their floras from Europe ; and the immigration of those floras necessitates the existence of a continuous, or nearly continuous, land-connection.

The larger depressions of the Gulf of Bothnia, the Baltic, the deep trough between Denmark and Norway, the long hollow in the bed of the Irish Sea, and some of the deep excavations in the sea-bottom between the Hebrides and the Scottish mainland, are represented as freshwater lakes. The rivers shown upon the now submerged areas follow the lines of deeper soundings.

PLATE E
Face page 568



EUROPE
in early Postglacial Times
(First Age of Forest)

ARCTIC OCEAN
ATLANTIC OCEAN
GULF STREAM
PREVAILING SOUTH WEST WINDS
Nova Zembla
North Cape
C. Kanin
Kolguev I.
Jan Mayen
Iceland
Cape Nord
Arms of Grede
Rockall I.
S. Kilda
Shetland Is.
Orkney Is.
Hebrides
Firth of Forth
R. Shannon
C. Clear
NORTH SEA
DENMARK
Heligoland
English Channel
Paris
R. Loire
Bay of Biscay
C. Finisterre
Pyrenees
R. Ebro
Madrid
C. Roca
Lisbon
St. Vincent
Str. of Gibraltar
Sierra Nevada
Malaga
Cartagena
Balearic I.
Sardinia
Corsica
Rome
Mt. Vesuvius
Sicily
Mt. Etna
Malta
MEDITERRANEAN SEA
Adriatic Sea
Ionian Sea
Aegean Sea
C. Matapan
Candia
Rhodes
Cyprus
Levant
Atlas
Morocco
AFRICA
R. Rhine
R. Elbe
Berlin
R. Oder
Hamburg
Bremen
Prague
Vienna
R. Danube
Alps
AUSTRIA
HUNGARY
Transylvania
Belgrade
SERVIA
Bulgaria
Balkan Mts.
ROUMANIA
BLACK SEA
Crimea
Sea of Azof
Caucasus Mts.
Mt. Elburz
Elburz Mts.
R. Aras
ASIA MINOR
Erzeroum
CASPIAN SEA
Astrakhan
Sea of Aral
Baku
R. Don
R. Dnieper
R. Dniester
Ukraine
Carpathian Mts.
POLAND
Warsaw
R. Vistula
Danzig
R. Niemen
Vilna
R. Pripet
Kiev
Kharkov
Orel
Moscow
R. Oka
R. Volga
Valdai Hills
Novgorod
Pskov
Petersburg
Ladoga
L. Onega
Gulf of Finland
Gulf of Bothnia
FINLAND
BALTIC
Gotland
Stockholm
Lofoden Is.
Varanger Fiord
LAPLAND
White Sea
Archangel
R. Dwina
Vologda
Kazan
Ural Mountains
Timan Mts.
R. Petchora
River Obi
R. Tobol
Tobolsk
SIBERIA
ASIA
RUSSIA
R. Ural
Orenburg
40
20
0
20
40
60
80
60
60
40
40
W Gr
O
E Gr
20
40
0
100
200
300
400
Scale of English Miles

London; Edward Stanford, 55 Charing Cross S.W.

INDEX.

Aar glacier, volume of water discharged from, 231 ; mud in water flowing from, 232.
Aberaeron, submarine forest at, 431.
Abich on ancient glaciers of Caucasus, 214.
Abruzzi, travertine of the, 56.
Acer campestre, 47, 49 ; *A. monspessulanum*, 49 ; *A. opulifolium*, 48, 49, 51, 52 ; *A. pseudo-platanus*, 50, 51, 53, 299, 305 ; *A. tribulatum*, 309.
Actæon, 502.
Acy, D', on origin of French *limon*, 165.
Adams, Leith, on breccias, etc., of Malta, 219, 327 ; on mammals of Ireland, 512.
Adhémar on rise of sea-level, 525.
Adimonia, 54.
Admiralty's charts of Mediterranean, 337.
Adrara, silted-up lake in valley of, 304.
Æsculus hippocastanum, 309.
African elephant, 27, 32.
Agardh cited, 497.
Agassiz, L., cited, 173, 176, 190, 197, 206.
Age of forests, 393, 455, 530, 537.
Agonum gracile, 54.
Ain, interglacial deposits in valley of the, 321.
Ajuga chamæpitys, 510.
Alactaga jaculus, 62, 149.
Albert, peat of, 480.
Alca impennis, 367.
Alder, 54, 420, 432, 436, 448, 480, 487, 494.
Aleppo pine, 48.
Algeria, raised-beaches of, 355.
Allagnon, moraines in valley of, 211.
Allier, interglacial deposits in valley of the, 318.
Alluvia, English postglacial, 455.
,, of Continent, 495.
,, relative position of Pleistocene and postglacial, 455, 495.
Alluvia, remains of Palæolithic man in, 22.
,, Scottish postglacial and recent, 407, 425.
Alnus glutinosa, 49, 487. (*See* Alder.)
Alpine hare, 32.
Alps, extent of glaciation on north side of, 208.
Altai pouched marmot, 62.
Amber in bed of the Elbe, 477.
Anodontæ, 299.
Ancylus fluviatilis, 470.
Androsace septentrionalis, 518.
Andromeda polifolia, 493.
Angermünde, freshwater clay at, 492.
Anglesey, glaciation of, 191.
Angular *débris* of last glacial epoch, 352.
Antilocapra rupicapra, range of, 31.
Antiquities, prehistoric, 5 ; classification of, 6 ; relative age of, how ascertained, 9.
Apennines, range of beech in, 47 ; ancient glaciers of, 213.
Aporrhaïs pes-pelicani, 468.
Apuan Alps, glaciation of, 213.
Arbor vitæ, 46.
Arbroath, raised-beaches near, 418.
Arcachon, submerged trees at, 481.
Arca raridentata, var. *major*, 467.
Archæological periods, 5.
Archiac, D', cited, 65.
Arctic-alpine plants, in peat of Switzerland, 54 ; migrations of, towards close of Glacial Period, 352 ; in English postglacial deposits, 456 ; below Danish peat bogs, 485 ; in clay below Swedish bogs, 491 ; below peat of Mecklenburg, 492 ; below peat of Bavaria, 493 ; in peat of Champagne, 493.
Arctic flora, in Pleistocene peat-bogs, 55, 262 ; in glacial beds, 262, 335 ; retreat of, in postglacial times, 505.
Arctic forests, 35.
Arctic fox, 27, 30, 32, 42, 55.
Arctic willow. (*See Salix polaris.*)

Arctomys bobac, 62, 149; *A. marmotta*, range of, 30.
Arctostaphylos alpinus, 353; *A. uva-ursi*, 456.
Arends cited, 479.
Arezzo, human remains in Pleistocene deposits near, 22.
Argelès, glacier of, 212.
Ariége, Neolithic cave-relics of, 377.
Arno valley, human remains in Pleistocene deposits of, 22.
Arvicola amphibius, 149; *A. gregalis*, 149; *A. nivalis*, 30; *A. ratticeps*, 62, 149; *A.* sp., 309.
Ås, åsar, 469, 470.
Ash, 50, 51, 320, 420, 432, 487.
Aspen, 469, 485.
Asturian flora, 508.
Atlas, moraines of the, 215.
Aubrac, ancient glaciers of, 211.
Aurillac, worked flint from Miocene of, 345.
Aurochs, 31, 103. (*See* Bison.)
Auvergne, glaciation of, 211.
Auzon valley, moraines in, 211.
Aveluy, peat of, 480.
Aygalades, tufa of, 49.
Ayrshire, raised-beaches of, 418.
Azalea procumbens, 353.
Azores, erratics in the, 214.

Badger, 87, 91, 97, 103, 107, 108, 480, 493.
Baglia Orba, ancient glacier of, 213.
Balænotus, 343.
Balanus, 284.
Balene-whale, 480.
Ballantrae, rock-terraces at, 275.
Ball on flora of the Atlas, 353; cited, 215.
Ballyalbanagh, human relics in peat-bog of, 462.
Baltic Sea, occupied by glacier-ice, 196; condition of, in interglacial times, 340; postglacial deposits on Swedish shores of, 468; freshwater terraces in islands of, 470; fish-fauna of, 471; depression in northern regions of, 471; erratics carried by floating ice in, 472; peat on Prussian shores of, 476.
Bänderthone, 284.
Barbary, raised-beaches of, 355.
Barnstaple, submerged forest at, 431.
Barrois on erratic conglomerate of Kerguillé, 226.
Barrows or tumuli, 375.
Barsebäck, raised-beach at, 475.
Bästekille, arctic plants in peat of, 491.
Baumannshöhle, 112.
Bavaria, peat of, 55, 493.
Bay of Fresnaye, submerged forest of, 481.
Bay of St. Anne, submerged forest of, 481.
Bear, 24, 25, 62, 87, 91, 138, 151.
Bear Island, 335.
Beaumont, Elie de, on origin of "erratic" phenomena, 173.
Beaver, 31, 32, 108, 262, 367, 373, 427, 449, 456, 480, 494.
Beech, 47, 49, 53, 436, 487.
Beech forests of Denmark, 487.
Belcher, Sir E., on vegetable remains on shores of Wellington Channel, 516.
Belfast Lough, Neolithic implements in shell-beds on shores of, 461.
Belgae, 376.
Belgian Caves. (*See* Caves.)
Belgium, peat on coast of, 479.
Belt on origin of löss, 162.
Bembidium nitidulum, 54; *B. obtusum*, 54.
Benghisa Gap, section of deposits in, 328.
Bennie cited, 256.
Bennigsen-Förder cited, 159.
Benoit cited, 209.
Berendt on glacial phenomena of North Germany, 198, 277; on boring near Schwielow-See, 280; on shell-beds between boulder-clays, 281.
Berlin, glacial deposits near, 284.
Bernhardi, A., on invasion of Germany by polar ice, 197.
Berwickshire, till of, 183.
Betula alba, 55, 299, 456, 492, 493; *B. nana*, 55, 456, 485, 492, 493, 497; *B. prisca*, 46; *B. pubescens*, 54, 152, 494; *B. verrucosa*, 487.
Beyrich cited, 283.
Bey, Pruner, cited, 21.
Biarritz, submerged trees near, 481.
Bideford Bay, submerged forest of, 431.
Bigbury Bay, submerged forest of, 431.
Biaty Dunajee, ancient glacier of, 210.
Bielshöhle, 112.
Binney cited, 190.
Birch, 54, 420, 432, 448, 488, 494.
Bird-remains, in Danish kitchen-middens, 367; in Swiss lake-dwellings, 373; in Flemish peat, 480; in peat of Champagne, 494.
Birsthal, interglacial deposits of the, 302.
Bison, 32, 40, 134, 373, 456.
Bison priscus, 62, 150.
Bithynia tentaculata, 280, 475.
Bischoff cited, 242.
Black alder, 302.
Black-earth of Russia, 157; distribution and extent of, 157; analyses of, 158; Murchison on, 158; origin of, 241.
Black-Forest, ancient glaciers of, 210; two glacial epochs in, 321.
Blackpool, submerged forest at, 431.
Blankenese, trees in bed of Elbe, near, 477.

Blaubeuern Cave, reputed Palæolithic pottery from, 18.
Bleau's Atlas cited, 425.
Blomstrand, M., cited, 497.
Blue fox, 107, 108.
Blytt, A., cited, 421; on succession of changes evinced by peat and buried trees in Norway, 488; on rate of growth of Norwegian peat, 489; on absence of arctic-alpine plants under Norwegian peat-bogs, 505; on distribution of plants in Norway, 515; on wet and dry periods in postglacial times, 527, 530; on successive forest-growths in Norway, 528.
Bodöe, range of temperature at, 35.
Bog-bean, 302.
Bog-whortleberry, 302.
Bohuslän, marine fauna of, 467.
Bois de la Bâtie, interglacial beds at, 301.
Boll cited, 201.
Bonaria, breccia of, 65.
Bone implements, 13.
Bones, carried into caves, etc., by running water, 95.
Bordeaux, range of temperature at, 39.
Boring near Schwielow-See, 280.
Borlase cited, 223.
Bornholm, submerged peat of, 476.
Bos etruscus, 317; *B. longifrons*, 404, 426, 447, 449, 456, 463 (*see* also Ox); *B. primigenius*, 62, 97, 284, 299 (see also Urus); *B. priscus*, 150; *B. taurus*, 494.
Boué, Ami, on human remains in Rhenish löss, 22; cited, 151.
Boulder-clay. (*See* Till.)
Bouquetin, 108.
Bourgeois, Abbé, on worked flints of St. Prest, 343; on Miocene implements, 345.
Bourguignat cited, 151.
Box, 50, 53, 320.
Brachycephali of Bronze Age, 376.
Bracklesham, submerged forest at, 431.
Brancaster Bay, submerged forests at, 450.
Brandon, interglacial beds of, 263.
Brandt cited, 29.
Braun, A., cited, 237.
Bravard cited, 318.
Break between Palæolithic and Neolithic Periods, 23, 120, 554.
Breccia and Blocks, in caves, 85; how accumulated, 85; in Brixham Cave, 86; in Kent's Cave, 91; of Corsica, 64; of Sardinia, 65; origin of, 215, 218; of Gibraltar, 325, 327.
Brentford, Pleistocene deposits of, 125, 138.
Brick-earth, origin of, 130.
Brickenden on glacial phenomena at Linksfield quarry, 185.
Bridlington, interglacial beds near, 264.
Bristol Channel, occupied by glacier-ice 192; submerged forests of, 431.
Britain, continental condition of, during last interglacial epoch, 266; submergence of, near close of last interglacial epoch, 266; condition of, during advance and retreat of last ice-sheet, 267; connection of, with Continent in early postglacial times, 507, 509; insulation of, in postglacial period, 524.
British area, geographical condition of, in Palæolithic times, 339.
Brittany, erratics in England derived from, 226; traces of glaciation in, 227; submerged forests of, 481.
Brittle willow, 50.
Brixham Cave, 3; deposits in, 86; not occupied in Post-pleistocene times, 119.
Broadheads, Neolithic, 376.
Broca cited, 21.
Brockdorf (Holstein), thickness of submarine peat at, 478.
Bronze Age, 6, 7, 8; in Switzerland, 374; in Britain, 375; in Scotland, 428; in Ireland, 463; in Denmark, 487; geological date of commencement of, 537.
Broughty Ferry, submerged peat at, 390.
Brown bear, 29, 32, 87, 97, 107, 108, 449, 456.
Bruhns cited, 200.
Buccinum grœnlandicum, 467; *B. humphreysianum*, 502; *B. undatum*, 277, 334, 399, 467.
Buckland cited, 77, 94, 174, 190.
Bulimus montanus, 57, 59; *B. obscurus*, 155.
Bulla, 284.
Buried forests of Tay and Earn, 386, 390; of Scotland, 419, 422; of Lancashire, 434; of Cornwall, 438; of Fenland, 448; of Ireland, 461.
Busk, list of mammalia in Brixham Cave, 87.
Bute, glaciation of, 178.
Buxus sempervirens, 49, 50, 53, 305. (*See* also Box.)
Buzzard, 480.

Cachalot, 480.
Cæcilianella acicula, 238.
Cæcum glabrum, 467.
Caermarthen Bay, submerged forest of, 431.
Caffer-cat, 25, 26, 32, 43.
Cagliari, breccia near, 65.
Cairndoon, raised-beach at, 418.
Caithness, shelly till of, 188, 267.
Caledonian bull, 427.
Callista convexa, 502, 503.
Calvados, submerged forests and peat of, 481.

Camischollas, interglacial and glacial deposits at, 298.
Campbell, J. F., cited, 190.
Campanula glomerata, 510.
Canary Islands, range of laurel in, 46.
Canary laurel, 46, 47, 50.
Canis lagopus, 30.
Cannibalism, no trace of, in Palæolithic accumulations, 22; supposed evidence of, in Neolithic times, 377.
Canoes in Scottish postglacial deposits, 392, 399; in Fenland deposits, 449.
"Canstadt race," 23.
Canstadt, tufa of, 46, 53, 59.
Cantabrian Mts., ancient glaciers of, 212.
Cantal, glacial remains of, 211; mammoth-remains in, 320.
Cape La Hougue, submarine trees near, 481.
Capellini discovers remains of pigmy hippopotamus at Spezia, 114; on cut bones in Italian Pliocene, 343; cited, 346.
Capercailzie, 367.
Capra ibex, 30; *C. pyrenaicus*, 30.
Cardigan, submerged forest of, 431.
Cardium edule, 277, 281, 284, 399, 434, 440, 441, 469, 475; *C. elegantulum*, 466.
Carlingford Bay, Neolithic implements in shelly deposits at, 461.
Carne cited, 440.
Carnoustie, raised-beach at, 418.
Carpathians, glaciation of the, 210.
Carpinus betulus, 52.
Carse-clay of Tay valley, 394; erratics in, 395; conditions of deposition of, 396; area of, 397.
Carse-deposits merge inland into river-gravels, 394, 401.
Carse of Falkirk and Stirling, 383, 399.
Carse of Gowrie, 383, 386.
Carvings, Palæolithic, 13.
Carychium minimum, 302.
Casco Bay, southern colonies in, 503.
Castelnau, tufa of, 45.
Castor europæus, 309.
Castro, gorge of, 305.
Caucasus, ancient glaciers of the, 214.
Cave-bear, 62, 87, 103, 107, 108, 111, 134, 147, 151, 261, 262, 321.
Cave-bear epoch, 112.
Cave-deposits of Pleistocene Period, 69, 90, 105.
Cave-earth, 84, 87, 91, 97.
Cave-hyæna, 62, 87.
Cave-lion, 87, 91, 103, 107, 108, 113, 134, 151, 325.
Cave of Santa Teresa, 114.
Caves, formation of, 69; varieties of, 70; age of, 72; absence of Pliocene deposits in, 73; destruction of deposits in, 74; floor-accumulations in, 75; contemporaneity of man and extinct mammalia of, 77; Neolithic accumulations in, 377.
Caves of Belgium, 100; general succession of beds in, 100; fluviatile deposits in, 101; break between Palæolithic and Neolithic deposits in, 120.
Caves of France, 110; Vallières, 110; Grotte des Fées, 110; Pontit, 111; Moustier, 111; Massat, 111; La Vache, 111; Bruniquel, 111; Eyzies, 112; Laugerie, 112; La Madelaine, 112; Gourdan, 112; Duruthy, 112; Sartenette, 112; La Salpétrière, 112; Bouichéta, 323; Sorde, 552.
Caves of Germany (Gailenruth, Muggendorf, Baumannshöhle, Bielshöhle), 112.
Caves of Southern Europe (Gibraltar, Mentone, Sicily, Malta), 114.
Caves of Switzerland (Kesserloch, Veyrier), 112.
Celtæ of Bronze Age, 376.
Celtis australis, 47, 49.
Cembran pine, 56.
Central France, volcanoes of, 320.
Ceppo, origin of, 316.
Cercis siliquastrum, 47, 49, 50.
Cervus sp., 309; *C. alces*, 299, 427; *C. dama gigantea*, 150; *C. dicranios*, 317, 336; *C. elaphus*, 299; *C. megaceros*, 318, 427, 436, 512; *C. pectinatus*, 318; *C. polignacus*, 262, 336; *C. tarandus*, 29, 36, 62, 87. (*See* also Elk, Irish deer, Red-deer, Reindeer, Roebuck.)
Chalky boulder-clay of East Anglia, 194.
Chambers, Robert, cited, 174, 411, 519.
Chambéry, interglacial beds of, 303.
Chamois, 31, 32, 103, 107, 108.
Champagne, peat of, 493.
Channel Islands, submarine trees of, 482.
Chantre cited, 208.
Chara, 425, 485.
Charnwood Forest, glaciation of, 268.
Charpentier cited, 207.
Chenopus pes-pelicani, 284.
Cherbourg, submarine forest near, 481.
Chert implements, Palæolithic, 12.
Cheshire, glaciation of, 189, 192; lower boulder clay of, 265; submerged forests of, 431, 432, 452.
Cheviots, local moraines of, 413.
Chiampo Cave, reputed Palæolithic pottery in, 18.
China, löss of, 165.
Chondrula tridens, 61, 238.
Chouquet cited, 50.
Christianiafjord, erratics from, in Jæderen, England, Denmark, Holland, etc., 203, 204.
Christol cited, 77.
Christy, H., cited, 42.
Cionella lubrica, 61, 238.
Classification of cave-relics, 15.

Clausilia dubia, 57, 61; *C. Kusteri*, 64; *C. laminata*, 57, 61; *C. parvula*, 57, 61.
Clay-with-flints, origin of, 220.
Clematis, 47.
Clematis flammula, 49; *C. vitalba*, 50.
Clermont-Ferrand, ancient moraines near, 210.
Cleveland, Ohio, interglacial beds near, 294.
Climate, changes of, independent of changes in relative level of land and sea, 521; Dr. Croll's theory of, 521.
Climate of Pleistocene Period, 25, 44; changes of, 39, 40, 331, 540; genial, 65; arctic, 67.
Climate of postglacial period, 514, 526, 527, 529, 554, 555.
Climatic and geographical conditions of Pleistocene Period, 331; of postglacial and recent period, 499.
Clonea, near Dungarvan, submarine peat of, 460.
Close, Rev. M., cited, 190.
Clupea harrengus, var. *membras*, 471.
Clyde, late glacial marine beds of the, 270; river alluvia of valley of the, 410.
Cocchi cited, 22; discovers glacial moraines in Apuan Alps, 213.
Cod, 367.
Coddrington, T., cited, 341.
Cogels, P., on borings in Belgium, 507.
Collegno, De, on glacial phenomena of Pyrenees, 173.
Collenot cited, 211.
Collomb, E., cited, 210, 212; on ancient glaciers of Corsica, 213; on volume of water discharged from glaciers of Ice Age, 231; on two glacial epochs in the Vosges, 322; on glacier of Argelès, 322.
Colonsay, glaciation of, 178; raised-beaches of, 418.
Common dogwood, 302.
Common maple, 47.
Como, morainic deposits near, 324.
Conditions of life, in Palæolithic times, 17; during formation of Danish shell-mounds, 368.
Conglomerate of Leffe, origin of, 310.
Contemporaneity of man and extinct mammalia, 77.
Contentin, submarine forests of, 481.
Continental condition of Britain in early postglacial times, 507.
Contorted beds of Glacial Period, 279. (*See* Till.)
Coot, 373.
Copper implements, rare, 7.
Corbula gibba, 469.
Cornelian Bay, Scandinavian erratics at, 192.
Corinth, Isthmus, raised-beaches of, 355.
Cornus sanguinea, 49, 53.
Cornwall, submerged forests of, 431; raised-beaches and submerged forests of, 437, 452.
Correlation of English postglacial deposits, 451.
Corsica, breccias of, 64; glaciers of, 213; depression of, in glacial times, 355.
Corylus avellana, 49, 50, 52, 53, 299, 309. (*See* also Hazel.)
Cossigny, De, on clay-with-flints of Paris Basin, 227.
Cotoneaster pyracantha, 49.
Cotta cited, 283.
Cottus scorpius, 469.
Courtmacsherry Bay, submarine peat of, 460.
Courtrai, borings at, 507.
Couze de Champeix, moraines of, 211.
Couze d'Issoire, moraines of, 211.
Crahay discovers human remains in Pleistocene of the Meuse, 22.
Cranberry, 302.
Crane, 373.
Crania, Palæolithic, 21.
Crannoges of Ireland, 463.
Cratægus oxyacantha, 49.
Credner, H., on glacial phenomena of Saxony, 199; on broken strata under till, 202; cited, 283, 301.
Crete, supposed former connection of, with Continent, 338.
Crié on flora of Mamers travertine, 52.
Criquebeuf, submarine forest of, 481.
Croll, J., cited, 39; on Caithness till, 188; on extent of northern ice-sheet, 197; theory of changes of climate, 254, 559; on rise of sea-level, 525.
Cro-Magnon, human remains in rock-shelter of, 21.
"Cro-Magnon-race" (Palæolithic), 23.
Cromer boulder-clay, 261, 263.
Crosskey, Rev. H., cited, 384, 385, 501.
Crow, 373.
Cumming, Rev. J., cited, 191.
Cut-bones, in Pliocene, 343; in Miocene, 346.
Cyclas, species of, in Swiss interglacial beds, 302; *C. cornea*, 149, 425, 434, 448.
Cyclopterus lumpus, 471.
Cyclostoma, species of, 57, 59.
Cygnus musicus, 494.
Cyprina islandica, 266, 281, 282, 284, 355, 399, 403, 497.
Cyprus, raised-beaches of, 355.
Cyrena fluminalis, 60, 137, 138, 264, 266.
Cystopteris fragilis, 508.
Cythere lutea, 284.
Cytheridea torosa, 493.

Dago, freshwater beds in, 470.
Dalserf, trees in peat near, 421.

Danewort or dwarf alder, 50.
Danzig, glacial deposits of, 284; peat near, 476.
Dargschichten, 477; formation of, 479.
Darwin, C., on Southampton gravels, etc., 141.
Dathe cited, 283.
Daubeny cited, 158.
David, Abbé, cited, 168.
Davies, Rev. E. J., cited, 214.
Dawkins, W. Boyd, on Palæolithic arrow-straighteners, 14; on classification of cave-relics, 16, 115; cited, 31, 65; on absence of Pliocene bone-accumulations in caves, 73; on Wookey Hole, 94; on deposits in Victoria Cave, 96; cited, 109; on Pleistocene hippopotamus, 134; on changes of level in Mediterranean area, 338; on cut-bones in Italian Pliocene, 345; on later prehistoric races, 376; on contrast between fauna of Palæolithic and Neolithic times, 380; on cause of "break in succession" between Palæolithic and Neolithic ages, 547; on relation of Palæolithic man to Eskimo, 548.
Débâcles, theory of, 172; of last glacial epoch, 352.
Debray on Flemish peat, 479; on peat of Somme, 480.
Débris, angular, origin of, 216, 224; of Scotland, 226; of North Carolina, 229; of last glacial epoch, 230.
Decay of peat-bogs, 532.
Decksand, 286.
Dee, submerged forests of the, 431, 432.
Deflections of ice-sheet in Scotland, 178, 188.
Defrance cited, 170.
Degner cited, 483.
Delaunay cited, 346.
Deluc cited, 171.
Denbighshire, submerged forests of, 431.
Denmark, interglacial deposits of, 283, 284; kitchen-middens of, 365; submerged peat of, 476; peat-bogs of, 485; arctic plants in, 485; succession of trees in bogs of, 485; human relics in bogs of, 487.
Dentalium abyssorum, 467, 502.
Denudation, rapid rate of, in Pleistocene Period, 127; modern, 128; A. Geikie on, 128.
Depression, area of, in North Atlantic and Arctic Oceans, 524.
Desnoyers on cut bones in deposits at St. Prest, 343.
Desor, E., cited, 207, 213; observations on Aar glacier, 231; on Pliocene glaciers, 324; cited, 346.
Devonshire, erratics in, 227; interglacial submergence of, 266; submerged forests of, 431; flora of, 508.
Dewalque on Sable Campinien, 507.
Differential motion of ice-sheet, 288.
Diluvium gris and *diluvium rouge*, 153.
Diluvium, upper and lower, of Germany, 280; of Holstein and Denmark, 283.
Disentis, glacial deposits near, 298.
Doe, G., cited, 227.
Dog, 103, 107, 367, 427, 463, 480, 494, 507.
Dogwood, 47, 53, 302.
Dolfus, observations on Aar glacier, 231.
Dolichocephali, Palæolithic, 23; Neolithic, 375.
Dol, submerged forests of, 481.
Domesticated animals in Swiss lake-dwellings, 373.
Domestic fowl, 480.
Dömitz, interglacial deposits near, 279.
Donaciæ, 480; *Donacia crassipes*, 494; *D. discolor*, 299; *D. sericea*, 299.
Dordogne, Caves of the, 12, 111; moraines in valley of the, 211.
Dormouse, 510.
Dorset, interglacial submergence of, 266.
Drance, gorge of the, glacial deposits in 298.
Drawings, Palæolithic, 13.
Dreissena, sp., 281, 282.
Drumkelin Bog, log hut in, 462.
Drums of till, 182.
Dryas integrifolia, 497; *D. octopetala*, 55, 485, 492, 493, 497.
Dublin County, kitchen-middens on shores of, 461.
Ducks, 373, 480.
Duncan's Flow Bog, ancient roadway in, 462.
Dundee, raised-beaches near, 418.
Dungarvan, submerged peat near, 460.
Dunkeld, morainic gravels at, 414.
Dunworly Bay, submerged peat in, 460.
Duparc, Chaplain, cited, 21; on rock shelter of Sorde, 552.
Dupont cited, 14; on Palæolithic pottery, 18; on Belgian caves, 100; on Trou du Frontal, 108; on position of löss in Belgian caves, 155.
Durham, glaciation of, 191.
Durham on buried forest and peat of Tay valley, 390.
Dürnten, interglacial bed at, 298.
Durocher cited, 195.
Duruthy, cave of, 21.
Dust storms, 166, 167.
Dwarf birch, 55, 485. (*See* also *Betula nana.*)
Dwarf pine, 47, 49.
Dwina, valley of, arctic shell-bed in, 471.

Earn valley, postglacial deposits of, 385, 390.
Eastbourne, submerged forest of, 431.
East Finmark, former wooded condition of, 488.

East Kilbride, large oaks in bog near, 421.
Eccentricity of earth's orbit, 559.
Ecliptic, obliquity of the, 560.
Eel, 367.
Eguisheim, human skull in löss of, 22.
Ehrenberg, *polythalamiæ* in Dargschichten, 478.
Ekaterinburg, glacial remains near, 210.
Elbe, trees in bed of, at Blankenese, 477.
Elephant, 24, 25, 26, 37.
Elephas africanus, 27, 113; *E. antiquus*, 27, 32, 49, 113, 133, 138, 299; *E. Falconeri*, 27, 32; *E. melitensis*, 27, 32; *E. meridionalis*, 22, 27, 32, 309, 317, 318, 320, 321, 336; *E. mnaidrensis*, 27, 32; *E. primigenius*, 62. (*See* also Elephant and Mammoth.)
Elm, 47, 52, 53, 320, 448, 494.
Elgin, ice-sheet in, 185.
El Kantara, moraines at, 214.
Ely, large erratic near, 193.
Engis cranium, 21.
England, succession of glacial and interglacial deposits in, 261; conditions of, during last interglacial epoch, 266; conditions of, during advance and retreat of last ice-sheet, 268; kitchen-middens in, 369; submerged forests of, 430; raised beaches of, 453; peat-bogs of, 454.
Engler on peat-flora, 495; on distribution of plants in Europe, 534.
English Channel, traces of interglacial submergence on borders of, 266; geographical conditions of, in Palæolithic times, 341; evidence of recent submergence on French coasts of the, 479-482; dry, in postglacial times, 509.
Enköpings ås, shell-bank on, 469.
Equisetum arvense, 494, 508; *E. limosum*, 299, 469; *E. variegatum*, 509.
Equus caballus, 149; *E. Stenoni*, 317.
Erdmann, A., on Swedish postglacial deposits, 465; on shell-bank at Enköping, 469; on raised-beaches of Scania, 474; on ancient hut at Södertelge, 474.
Erdmann, E., cited, 195, 270; on raised-beaches of Scania, 475; on littoral shell-bed at Gothenburg, 506.
Eriophorum, 493; *E. angustifolium*, 508.
Ermine, 107.
Erratics, 107, 133, 148, 171, 285, 386, 395, 472; abnormal distribution of, 203, 564.
Errol, arctic shells in clay at, 387.
Ertborn, Baron v., on borings at Menin and Courtrai, 507.
Eskimo, supposed relation of, to Palæolithic man, 547.
Estuarine flats, 383, 394, 417.
Etchings, Palæolithic, 13.
Euonymus europæus, 49, 50, 53; *E. latifolius*, 50.
European nettle-tree, 47.
Europe, climate of, 33; impossibility of great annual migrations of mammals in, 36; temperature of certain places on west coasts of, 39; climate of, in Pleistocene Period, 40; conditions of, during melting of last ice-sheet, 347; conditions of, during last interglacial epoch, 348; conditions of Central, in postglacial period, 522; conditions of Southern, in postglacial period, 533; central and north-west regions of, probably not occupied by man in late glacial and early postglacial times, 553.
Evans, J., cited, 3; on probable uses of Palæolithic implements, 12; remarks on bone-pin from Kent's cave, 17; on contrasts between Palæolithic and Neolithic implements, 24; cited, 341, 345.
Evergreen oak, 47, 48.
Excavation of valleys in Pleistocene times, 88.

Færöe Islands, glaciation of, 206, 504, 567; peat and buried trees of, 514; present flora of, 518.
Fagus sylvatica. (*See* Beech.)
Falcon, 373.
Falconer cited, 3, 49, 457.
Fallow-deer, 113, 427.
Falmouth, submerged forest near, 431.
Falsan, A., cited, 207; on shells in moraine of Rhone glacier, 327.
Falsterbo, submarine peat and raised-beach near, 473.
Faudel cited, 22.
Fauna. (*See* Birds, Fish, Insects, Mammalia, Mollusca.)
Favre on deposits at Bois de la Bâtie, 301.
Faxö, interglacial and glacial deposits of, 285.
Fegatella conica, 49.
Felis caffra, 26 (*see* also Caffer Cat); *F. leo*, 26; *F. pardus*, 27 (*see* also Leopard); *F. serval*, 27 (*see* also Serval); *Felis spelæa*, 26 (*see* also Cave-lion).
Fenland, traces of interglacial submergence in, 266; sunk forests and peat of, 445, 452.
Ferrero on glaciation of Apennines, 213.
Ferry, De, on reputed Palæolithic pottery, 18; estimate of antiquity of Neolithic Age, 558.
Festuca ovina, 508.
Ficus carica, 47, 49, 50.
Fig-tree, 47, 48, 50, 52.
Filhol on Neolithic relics in Pyrenean caves, 377.
Fine, valley of the, 344.

Finland, glaciation of, 196 ; postglacial deposits of, 470.

Fir, 469, 480.

Firth of Forth, shell-mounds of, 369 ; post-glacial deposits of, 399 ; raised-beaches of, 418.

Fisher, Rev. O., on erratic in Roslyn Hole, near Ely, 194.

Fish, in interglacial beds of Val Borlezza, 305 ; in Danish kitchen-middens, 367 ; of Swiss lake-dwellings, 373 ; of Baltic Sea, 471 ; in Flemish peat, 480.

Flemish coast, peat of, 479.

Fliche, P., on Jarville lignite, 54 ; on peat of Champagne, 493.

Flint implements, early discoveries of, in England, 4 ; Palæolithic, 12.

Floating-ice, evidence of, in Carse-clays, 396 ; traces of, in Scandinavian postglacial deposits, 472.

Flood-deposits, interglacial, 264 ; glacial, 269 ; of last glacial epoch, 352.

Floods, of Glacial Period, 232, 235 ; effects of, upon deposits of last interglacial epoch, 359.

Floor-accumulations in caves, 75.

Flora. (*See* Plants.)

Flounder, 367.

Flustra, 447.

Fluviatile alluvia, remains of Palæolithic man in, 22.

Fluvio-glacial deposits covering accumulations of last interglacial epoch, 359.

Folliculites newirthianus, 309.

Forbes, E., on geological relations of British fauna and flora, 508 ; on former land-connection of Færöe Isles and European continent, 518.

Forbes, J. D., cited, 174.

Forchhammer cited, 366 ; striated rocks of Faxö, 196 ; submerged peat of Denmark, 476.

"Forest-bed" of Norfolk coast, 261, 334.

Forests, of Arctic regions, 35 ; first great extension of, in genial postglacial period, 522 ; second extension of, in later postglacial period, 528 ; decay of, in historical times, 530.

Forfarshire, shell-mounds of, 369.

Fort Confidence, range of temperature at, 34.

Fort-William, shell-bed at, 385.

Forth, late glacial marine beds of the, 270.

Fox, 31, 32, 87, 91, 97, 103, 107, 108, 113, 262, 367, 373, 427, 449, 463.

Fox, Arctic. (*See* Arctic fox.)

Fox, General Lane, cited, 7.

Fox, Rev. Mr., cited, 341.

Fraas cited, 18, 346.

France, caves of, 15 ; plains of, invaded by Swiss ice, 208 ; evidence of glacial action in Northern, 223 ; Central, glaciation of, 211 ; clay-with-flints of, 220 ; supposed kitchen-middens in, 369.

Franconia, list of shells in löss of, 61 ; list of mammals in löss of, 62.

Fraxinus excelsior, 49, 50 ; *F. ornus*, 47, 48, 49, 51.

Frere, J., cited, 123.

Freshwater shells in bed of Elbe, 477.

Frisches Haff, glacial deposits near the, 281.

Frogs, 373.

Fuchs, Th., cited, 237.

Fucus canaliculatus, 497.

Fuhlrott cited, 21.

Fulda, löss in valley of the, 146.

Funen, submerged peat of, 476.

Fustic, 47.

Gadus morrhua, 471.

Gailenruth Cave, 112.

Galium palustre, 299.

Gallican flora in Southern England, 509.

Gandino, lignites near, 306 ; damming of basin of, 307.

Gäravallen, 473.

Garonne, löss in valley of the, 146 ; ancient glacier of the, 211, 323.

Garrigou on two glacial epochs in Pyrenees, 323 ; on Neolithic relics in Pyrenean caves, 377 ; on hiatus between Palæolithic and Neolithic ages, 554.

Gastaldi cited, 113.

Gaudin cited, 45.

"Geest," 477.

Geikie, A., on modern denudation, 128 ; on origin of löss, 162 ; on glacial striæ in Caithness, 188 ; on interglacial deposits, 253.

Geinitz, F. E., on glacial phenomena in Mecklenburg-Schwerin, 202, 279.

Geographical changes in Pleistocene Period, 331 ; in last interglacial epoch, 348.

Geographical conditions during last glacial epoch, 350 ; during postglacial and recent period, 499.

Geotrupes putridarius, 494 ; *G. stercorarius*, 260 ; *G. vernalis*, 494.

Gerdauen, sand of, 287.

Germani, 376.

Germanic flora, 508.

German Ocean. (*See* North Sea.)

Germany, caves of, 112.

Geschiebesand, 286.

Gibraltar, breccias of, 216 ; interglacial beds of, 324.

Gilliéron, estimate of antiquity of Neolithic Age, 358.

Giraldus Cambrensis cited, 456.

Girard cited, 283.

Gironde, submerged forests of, 481.

Girvan, raised-beach near, 418.

Glacial epoch, the last, deposits of, 285; conditions during, 350; extent of glaciation during, 503.
Glacial Period, 169; general conditions of Europe during, 247; climatic conditions of, 248; a phase of Pleistocene Period, 250; man contemporaneous with, 250; succession of changes during, in Germany, 286; conditions at close of, 354; identity of, with Pleistocene Period, 539.
Glacial phenomena, description of, 174; smoothed and striated rocks, 175; *roches moutonnées*, 176; *Stoss-seite* and *Lee-seite*, 177; upper limits of glaciation, 177; deflection of glacial striæ, 178.
Glacial shelly clays of Norway and Sweden, 467.
Glen Beansdale, glacial phenomena in, 416.
Glen Brora, postglacial moraines of, 411.
Glen Iorsa, moraines at mouth of, 411.
Glen Messan, moraines of, 411.
Glen Turret, moraines of, 413.
Gloves, Palæolithic, 17.
Glutton, 24, 29, 32, 55, 62, 113, 147.
Goat, 103, 107, 373, 427, 463.
GOEBEL cited, 158, 242.
GODWIN-AUSTEN on "head" of Cornwall, etc., 224; cited, 442, 507, 509.
Golden eagle, 373.
GOODCHILD cited, 190.
Goose, 373.
Gottland, erratics from, 282.
Gourdan, cave of, 21, 22.
Goyet, cave of, 107.
GRAD, Ch., temporary glaciers in Vosges Mountains, 210; moraines at El Kantara, 215.
GRANDSAIGNES, T. de, ancient glaciers of Corsica, 213.
Gravels, high- and low-level, 132; coarse angular, in south of England, 140.
Grays, Pleistocene deposits at, 125, 138.
Gray willow, 47, 49, 50. (*See* also *Salix cinerea.*)
Great auk, 367.
Great chalky boulder-clay, 263.
Great Grimsby, submerged forest near, 431.
Great ox. (*See* Urus.)
Greek periploca, 47.
Greenland, mud from glaciers of, 231; immigration of flora of, 519.
Green-leaved alder, 54.
GREENWELL, Rev. W., on supposed evidence of cannibalism in Neolithic time, 377.
Greflunda, arctic-alpine flora in peat of, 491.
GREPPIN on interglacial deposits of the Birsthal, 302.
GREWINGK on red-deer in Kurland, 496.
GRIFFITHS, Sir R., cited, 189.
GRISEBACH on peat of East Friesland, 478; cited, 531.
Grisly bear, 29, 32, 87, 97, 103.
Grouse, 373.
Gulf of Bothnia, formerly a freshwater lake, 470.
Gulf of Finland, formerly a freshwater lake, 470.
Gulf of St. Lawrence, southern colonies in, 502.
Gulf Stream, 39; former larger volume of, 503.
Gull, 373.
Gulo borealis or *luscus*, 29, 62. (*See* also Glutton.)
GUMÆLIUS cited, 195.
GÜMBEL, on origin of löss, 160.
Gute Herberg, peat on Baltic coast at, 476.
GUYOT cited, 207.
GYSSER cited, 238.

HAILES QUARRY, interglacial deposits at, 256.
HALL, Sir J., cited, 172.
Hamilton, white cattle at, 427.
Hammers, Palæolithic, 12.
Hampshire gravels, 341.
HAMY on types of Palæolithic man, 23; on human remains at Sorde, 552.
Hanover, submerged peat of, 476.
Hardman cited, 190; on submerged peat of Tramore Bay, 459.
Hare, 31, 87, 97, 103, 107, 108.
Hartlepool, submerged forest near, 431.
Hart's-tongue. (See *Scolopendrium officinale.*)
HARTUNG cited, 215.
Harz, caves of the, 112.
Hastings, submerged forest near, 431.
HAUER, F. V., cited, 150.
Hayle, submerged forest near, 431.
Hazel, 47, 50, 52, 53, 302, 420, 432, 435, 438, 448, 480, 487, 494. (*See* also *Corylus avellana.*)
"Head" of Cornwall, 224, 225, 227, 437.
Heath-lands of Northern Germany, 484.
Hedera helix, 49, 50, 515.
Hedgehog, 321, 367.
HEER cited, 46; on flora of Canstadt tufa, 53; on Dürnten lignite-beds, 298, 300; on interglacial beds of the Birsthal, 302; on cereals in Swiss lake-dwellings, 373; on postglacial flora of Bovey Tracey, 456; on arctic-alpine flora of Switzerland, 495.
HEIM, A., cited, 301.
Heleocharis multicaulis, 515.
Helix, lists of species of, 56, 59, 61, 64, 148, 152, 155, 302.
HELLAND, A., cited, 188; on Scandinavian erratics in Holderness, 192; on broken rocks, etc., under till of Saxony,

201 ; on glaciation of Færöe Isles, 206, 504 ; on mud in glacial rivers of Greenland, 232 ; on Norwegian strandlinier, 272 ; cited, 514, 566, 567.
Helsingborg, raised beach near, 475.
Helston, submerged forest near, 431.
Hercynian Forest, reindeer in, 535.
Heron, 373.
Herring, 367.
Hessle, interglacial beds of, 265 ; boulder-clay of, 266.
HEYNEMANN cited, 237.
HIBBERT on origin of Rhenish löss, 159.
Hill-löss, 146.
Hill-ranges of Central Scotland, contour of, 180.
HINDE, G. J., on interglacial deposits near Lake Ontario, 293.
Hinlopen Strait, mussel-beds of, 497.
Hippopotamus, 24, 25, 32, 97, 113, 134, 261 ; pigmy, 114, 338.
Hippopotamus amphibius, 28, 336 ; *H. liberiensis,* 26 ; *H. major,* 26, 113, 138, 317, 320 (*see* also Hippopotamus) ; *H. Pentlandi,* 26, 33, 113 (*see* also Hippopotamus, pigmy.)
HISINGER on ancient hut at Södertelge, 474.
HOERNES cited, 355.
HOFF, A. V., cited, 538.
HOGARD cited, 209.
Holderness, Scandinavian erratics in, 192.
Holopleura victoria, 299.
Holme, submarine forests at, 450.
Holland, peat and buried forests of, 477.
HOLMSTRÖM cited, 196, 270.
Holstein, interglacial deposits of, 283 ; submerged peat of, 476.
Holyhead, submarine peat near, 431.
HOOKER, Sir J. D., moraines of Lebanon, 214 ; moraines of the Atlas, 215 ; on pine from Wellington Channel, 516 ; on postglacial genial period, 517 ; on flora of Greenland, 518.
HÖRBYE on glaciation of Norway and Sweden, 194.
Hordeum distichum, 403 ; *H. hexastichon,* 373.
Hornbeam, 52, 302, 320.
HORNE, J., on glaciation of Orkney and Shetland, 188 ; on glacier of Theiss valley, 209 ; on late glacial marine deposits on borders of Moray Firth, 270.
Horse, 31, 32, 40, 87, 97, 103, 107, 108, 133, 138, 147, 148, 149, 151, 261, 321, 325, 427, 480, 507.
HOWDEN on glacial and post-glacial deposits near Montrose, 403.
Huel Darlington mine, section of, 440.
HULL cited, 190, 191 ; on glacial deposits of north-west of England and Ireland, 265.
Human relics in Scottish peat-bogs, 424.
Human remains, rarity of, in Palæolithic accumulations, 20 ; in löss, 151 ; in Pleistocene of Olmo, 318 ; in Scottish postglacial beds, 402 ; in English postglacial beds, 438, 439, 440 ; in Irish peat, 461 ; in French peat, 480.
Humber, glacial and interglacial deposits in valley of the, 264 ; submerged forests of the, 431.
HUME, Rev. Dr., cited, 432.
Humid climate and submergence of land, connection between, 452.
Humid climate in Glacial Period, 230 ; in postglacial period, 527, 529.
HUMMEL cited, 195.
Hungelbrunn, löss of, 237.
Hvitaby, arctic flora in peat of, 491.
Hyæna brevirostris, 321 ; *H. crocuta,* 27 ; *H. spelæa* (cave-hyæna), 27, 62, 91, 103, 107, 108, 111, 113, 114, 147 ; *H. striata,* 27.
Hyæna-dens, 94, 98, 107.
Hyæna, species of, 27.
Hyaliniæ, list of, 56.
Hydrobia marginata, 60 ; *H. ulvæ,* 384.
Hylobius rugosus, 299.
Hymenophyllum Wilsoni, 515.
Hypnum aduncum, 55, 494 ; var. *polycarpon,* 494 ; *H. cordifolium,* 485 ; *H. cuspidatum,* 492 ; *H. fluitans,* 450, 492, 494 ; vars. *falcatum* and *submersum,* 494 ; var. *tenuissimum,* 55 ; *H. giganteum,* 492, 494 ; *H. lignitorum,* 299 ; *H. pratense,* 494 ; *H. priscum,* 299 ; *H. sarmentosum,* 55 ; *H. scorpioides,* 492, 496 ; *H. turgescens,* 262, 335.

IBERIAN flora in Ireland, 508, 509, 514.
Ibex, 30.
Iceberg theory of glacial deposits, 174.
Iceland, glaciation of, 519 ; connection of, with European continent in postglacial times, 520.
Ice-sheet, of Northern Europe, 205 ; of last interglacial epoch, 267 ; retreat of, in British area, 269 ; morainic *débris,* etc., in Germany of last, 285 ; preservation of deposits below, 288 ; differential motion of, 204, 288 ; effect of, upon preglacial and interglacial beds, 289 ; of last glacial epoch, 350 ; effect produced by, on deposits of last interglacial epoch, 356.
Ilex aquifolium, 49.
Ilford, Pleistocene deposits of, 137.
Implements, Palæolithic, 11 ; Neolithic, 366, 368, 372.
Inches of Tay valley, 387.
Infusoria-earth, interglacial, 279.
Insects of Swiss interglacial beds, 299 ; of English postglacial beds, 440 ; of Flemish peat, 480.

Interglacial fauna and flora identical with those of Pleistocene alluvia, etc., 540.
Interglacial deposits, of Scotland, 255, 291 ; at Hailes Quarry, 256 ; of England, 261 ; of Brandon, 263 ; of Holderness, 264 ; of Ireland and north-west of England, 265 ; of last interglacial epoch, 266 ; of Scandinavia, 270 ; of Rixdorf, 278 ; of Kreuzberg, 279 ; of Dömitz, 279 ; of Tempelhof, 280 ; of Province of Prussia, 281 ; of Elbing, 281 ; of Saxony, 282 ; of Faxö, 285 ; general succession of, in Germany and Denmark, 286 ; preservation of, under till, 288, 316 ; of Switzerland, 297 ; of the Drance, 298 ; of Dürnten and Utznach, 298 ; of Bois de la Bâtie, 301 ; of the Birsthal, 302 ; of Chambéry, 303 ; of Italy, 303 ; of Val Borlezza, 304 ; of Val Gandino, 306 ; of Leffe, 306 ; of Val Adrara and Val Foresto, 315 ; of Upper Val d'Arno, 317 ; of Perrier, 318 ; of the Valley of the Ain, 327 ; of the Rhone Valley, 321 ; of the Black Forest, 321 ; of the Vosges, 322 ; of the Pyrenees, 321 ; of Gibraltar, 324 ; of Malta, 327 ; effect of last ice-sheet upon, 356 ; effect of floods upon, 359 ; buried under löss, 359.
Interglacial epochs, earliest recognition of, 252 ; Morlot on, 252, 297 ; Ramsay on, 253 ; A. Geikie on, 253 ; volcanoes of Central France active during, 320. (*See* also Interglacial Deposits.)
Inundations. (*See* Floods.)
Ipswich, interglacial beds at, 263.
Ireland, glaciation of, 189 ; glacial and interglacial deposits of, 265 ; submergence of, in last interglacial epoch, 266 ; kitchen-middens in, 369 ; raised-beaches of, 458 ; former connection of, with Scotland, 512 ; postglacial submergence in, 526.
Irish deer or elk, 31, 91, 107, 261, 262, 427, 435, 442, 449, 456, 463.
Irish Sea, depths in, 339 ; dry land in area of, in postglacial times, 509 ; large lake-basin in bed of, 511.
Iron Age, 6, 7, 9 ; in Denmark, 487 ; in Britain, 538, 556.
Isle of Man, glaciation of, 191.
Isle of Wight, formerly joined to mainland, 341.
Isocardia cor, 467.
Italy, reputed Palæolithic pottery in caves in, 18 ; caves of, 114 ; glaciation of Northern, 209 ; interglacial deposits of, 303 ; reputed Pliocene glaciers of, 324 ; traces of submergence in, during Glacial Period, 355.
Ivy, 47, 50.

Jack, R. L., on glaciation of East Carpathians, 209.
Jæderen, erratics in, 204 ; peat of, 489.
Jakutsk, temperature of, 34.
Jamieson, T. F., on shells in Carse-clays, 395.
Järavallen, 473.
Jarville, lignite of, 54.
Jasione montana, 515.
Jeffreys, Gwyn, on shell-bed at Fort-William, 385 ; cited, 467, 502, 506, 509.
Jentzsch cited, 237, 245 ; on German glacial deposits, 277, 281 ; on stones of southern derivation in till of Saxony, 283.
Jerboa, 62, 147.
Johnstrup on glaciation of Denmark, 196 ; on glaciation of Möen, 200.
Jökulsfjord, strandlinier in, 274.
Judas-tree, 47, 48, 50.
Judd, J. W., cited, 194.
Juglans bergomensis, 309 ; *J. paviæfolia*, 46 ; *J. regia*, 49.
Jukes, J. B., cited, 190.
Julien, A., cited, 317, 318 ; on deposits of Mont Perrier, 318 ; on two glacial epochs in the Pyrenees, 323.
Juncus triglumis, 353.
Juniper, 54, 420, 494, 514.
Jura Mountains, caves of, 112 ; invaded by ancient Rhine glacier, 208 ; extinct glaciers of, 209.
Jutland, recent submergence in, 367 ; submerged peat of, 476.

Kalamaki, raised-beaches of, 355.
Kamp valley, Palæolithic remains in, 151.
Kane cited, 240.
Kattegat, kitchen-middens on shores of, 365, 369.
Keilhau cited, 194.
Keller on lake-dwellings, 370 ; on passage from Neolithic into Bronze Age, 374 ; on earthenware crescents, 375.
Kellia rubra, 467.
Kennet valley, postglacial remains in, 457.
Kentish type of flora, 508.
Kent's Cave, implement from lowest deposit in, 11 ; bone pin from, 17 ; early researches in, 77 ; rate of stalagmitic accretion in, 81 ; succession of deposits in, 90 ; human relics and mammalian remains in, 91 ; "break in succession" in, 119.
Kerguillé, erratic conglomerate at, 226.
Kerrera Sound, raised-beach in, 418.
Kerr, W. C., on angular drift of North Carolina, 229.
Kesserloch, etching of reindeer from, 14.
Kilcredane Point, submarine peat at, 460.
Killybegs, range of temperature at, 39.

Kilroot, Neolithic implements at, 461.
Kinahan cited, 190; on Irish peat-bogs, 461; on rate of growth of Irish peat, 490; cited, 528.
Kincardine Moss, 422, 424.
King, Clarence, cited, 243.
Kingsmill cited, 168.
Kirkdale Cave, 94.
Kitchen-middens, Danish, 365; men of Danish, 368; in Scotland, England, Ireland, and France, 369; in Carse of Falkirk, 400; in Ireland, 461.
Kjerulf cited, 195; on Norwegian strandlinier, 271; on heights reached by Norwegian glacial shell-beds, 271; on postglacial shell-beds of Norway, 465; on unfossiliferous postglacial clay of Norway, 471.
Klein, shells of Canstadt tufa, 46, 59.
"Knick," 477.
Kolbermoor, peat of, 493.
Königsberg, range of temperature at, 39.
Korzistka cited, 146.
Krapotkin, on postglacial beds of Finland and Northern Russia, 470.
Kreuzberg, interglacial deposits of, 279.
Kunth on German glacial deposits, 277.

Labrador current, 39.
La Celle, tufa of, 50, 56.
Lacuna divaricata, 385.
Lacustrine alluvia, postglacial, 425.
Lago d'Iseo, ancient glacier of, 303.
Lagomys, 108, 113, 149. (*See* also Tailless Hare.)
Lagomys corsicanus, 30; *L. pusillus*, 30; *L. sardus*, 30.
Lahn, river, löss of, 145.
Lake district (Northern England), glaciation of, 190.
Lake-dwellings, 369.
Lake, former, in bed of Irish Sea, 511.
Lake of Bienne, silting up of, 558.
Lake of Onega, height of, above sea, 471.
La Madelaine Mountains, glaciation of, 212.
Lamanon cited, 172.
Lamplugh on interglacial beds near Bridlington, 264.
Lancashire, glaciation of, 190; lower boulder clay of, 265; submerged peat of, 431, 432; postglacial beds of, 451.
Land-connections between Europe and Africa in Pleistocene times, 337; disappearance of, 523, 533.
Land, great extension of, in early postglacial times, 505, 509, 513, 518.
La Pique, glacier of, 212.
Larch, 54.
Largo, submarine peat at, 401.
Larix europæa, 309.
Lartet cited, 21, 29, 49, 111, 552.
Lasard cited, 283.
Late glacial deposits in Tay and Earn valleys, 386.
Laurus nobilis (laurel), 46, 47, 49; var. *Canariensis* (Canary laurel), 46, 47, 49, 50.
Laurustinus, 47.
Leda arctica, 281, 387, 403, 471; *L. pernula*, 467.
Lee-seite, 177.
Leffe, lignites of, 306.
Lehm. (*See* Löss.)
Leipzig, striated rocks near, 198.
Lemming, 30, 32, 40, 42, 62, 87, 108, 147, 149.
Leopard, 27, 32, 40, 113, 325.
Lepidoptera, distribution of alpine species of, in Britain, 511.
Lepus timidus, 510. (*See* also Hare.)
Leuchars, raised-beach at, 418.
Lewis, island of, 268.
Leydig cited, 237.
Lignite, of Steinbach, 152; interglacial, 298, 303.
Lillemose, peat-bog of, 485.
Lima excavata, 467.
Limax agrestis, 61.
Lime-tree, 48, 53.
Limnæa, 425, 449; *L. limosa, β ovata-normalis*, 475, 493; *L. minuta*, 302; *L. ovata*, 57, 470; *L. peregra*, 264.
Limon grossier (Limon biéfeux), 154, 163.
Limon hesbayen, 155, 507.
Lincolnshire, submarine peat of, 431, 450.
Lindeberg on successive tiers of trees in bogs of Sweden, 488.
Lindsay, Lauder, cited, 518.
Lindström cited, 195.
Linth, E. v., cited, 206.
Lion, 26, 32. (*See* Cave-lion.)
Liparis barbatus, 171.
Lipari, tufa of, 45, 47.
Liquidambar europæum, 46.
Lithuanian bison, 31.
Littel cited, 150.
Little Sole Banks, trace of submerged littoral deposits at, 509.
Littorina, 284; *L. litorea*, 399, 469, 497.
Littorinella, 284.
Loamy deposits of Pleistocene Period, 143.
Local glaciers, postglacial, 526; in Scotland, 398, 411; deflection of, 415.
Locard on shells in Pleistocene at Lyons, 63; on shells in Corsican breccias, 64; on breccia of Bonaria, 65.
Loch Skene, moraines at, 412.
Looes, submerged peat near the, 431.
London, submerged peat at, 431.
"Longheads," Neolithic, 375.
Lory cited, 208.
Löss, human remains in, 22; composition

of, 144; concretions in, 144; fossils in, 144; vertical capillary structure of, 144, 237; traces of bedding in, 144, 237; Rhenish and Danubian, 145, 236; passes into clay and loam, 145; distribution of, in Europe, 145; mammalian remains in, 147, 150, 239; deposits of, at Thiede and Westeregeln, 147; human remains and relics in, 150; character of, near Tübingen, 151; deposits underlying, in river-valleys, 152; section of, at Steinbach, 152; character of, in French river-valleys, 152; appearance of, in Northern France, 153, 236; fossils in French, 154; Belgian, 154; not a separate and independent formation, 156; theories of origin of, 130, 159, 233; marine and lacustrine theories of, 160; Mr. Belt's theory of, 162; De Mercey on French, 163; Richthofen on, 165; of China, 165; Pumpelly on, 167; sporadic stones in, 237; shells in, 237.
Lösskindeln, Lössmännchen, Lösspüppchen, 144.
Löss-shells, list of, 60.
Lovén on former direct connection of Baltic with Arctic Ocean, 470.
Lower Pentewan work, section of, 439.
Llandrillo Bay, submarine forest at, 431.
Lubbock, Sir J., on Danish kitchen-middens, 366.
Lumaki, raised-beaches of, 355.
Luncarty, river-gravels at, 386.
Lusitanian-Mediterranean molluscs in Norwegian shell-beds, 468.
Lyell, Sir C., cited, 3, 124; on Pleistocene of Thames valley, 137; on löss near Tübingen, 151; on origin of löss, 159; on glacial phenomena in Möen, 200; on recent submergence of Jutland, 367; cited, 457; on erratics at Upsala, 472; on buried hut at Södertelge, 474.
Lymfjord, kitchen-middens in, 365.
Lynx, 31, 107, 113, 367.
Lyons, list of shells in Pleistocene of, 63.

MacEnery, Rev. J., discoveries in Kent's Cave, 4; cited, 77.
Machairodus latidens, 26, 33, 262, 336.
Mackintosh, D., cited, 191.
Maclaren, C., cited, 174, 411.
Mactra elliptica, 502; *M. solida*, 277, 281; *M. subtruncata*, 284.
Magnolia, sp., 305.
Mainporth, submerged forest at, 431.
Main, river, löss of, 145; flood-deposits of, 238.
Major, Forsyth, on mammalian remains in Leffe lignite, 309.
Malaga, raised-beaches at, 355.
Malm cited, 467.
Malmgren on fish of Baltic, 471; on shell-beds of Spitzbergen, 497.
Malta, rock-fissure of, 114; breccias of, 219, 327.
Mamers (Sarthe), travertine of, 52.
Mammalian fauna of genial postglacial period, 523.
Mammals of Pleistocene Period, 25; commingling of northern, southern, and temperate groups of, 33, 37; large size of, 40; list of, in Franconian löss, 62; in Brixham Cave, 87; in Kent's Cave, 91; in Victoria Cave, 97; in Belgian caves, 103, 107; in caves of Southern Europe, 113; in river-gravels, 133, 134; in Pleistocene of Thames valley, 138; in löss, 147, 148, 149; in Forest-bed of Norfolk, 261, 334, 336; in German interglacial beds, 279; in lacustrine deposits of Pianico, 304; in Leffe interglacial beds, 309; in deposits of Val d'Arno, 317; in Gibraltar caves, etc., 325; in Danish kitchen-middens, 367; in Swiss lake-dwellings, 372; in Scottish postglacial deposits, 426; in English postglacial and recent deposits, 436, 438, 439, 440, 447, 456; in Irish postglacial deposits, 463; in Flemish peat, 480; in French peat, 480, 493.
Mammoth, 17, 24, 25, 32, 42, 62, 87, 91, 103, 107, 108, 111, 113, 133, 147, 148, 149, 150, 151, 262, 507; postglacial, 457.
Mammoth oak, 53.
Mammoth period, 101, 112.
Manna ash, 47, 48, 51, 52.
Map of Europe at the climax of Glacial Period, 564.
Map of Europe, during First Age of Forests, 568.
Maples, 47, 48, 53.
Marash, stony clay of, 214.
Marazion Marsh, section of buried forests, etc., in, 440.
Margarita costulata, 466; *M. undulata*, 466.
Marion cited, 46.
Maritime Alps, extinct glaciers of, 212.
Mark Brandenburg, interglacial deposits of, 280.
Marmot, 30, 32, 40, 42, 62, 107, 113, 147.
Marocco, morainic mounds on plains of, 214.
Marseilles, tufa near, 49.
Marten, 31, 32, 367, 373, 449.
Martin, J., cited, 210.
Martins, Ch., on origin of flora of peat-bogs, 495; cited, 195, 207; on Argelès glacier, 212.
Massa Marittima, travertine of, 46.
Massenat cited, 21.

Mastodon arvernensis, 317 ; *M. Borsoni*, 321 ; *M. longirostris*, 317.
MAYER on Pleistocene of Val d'Arno, 317 ; on so-called Pliocene glacial deposits, 324.
MAW, G., on glacial phenomena of the Atlas, 215.
Mawnan, submarine forest near, 431.
Meath, kitchen-middens in, 461.
Mecklenburg, arctic plants in freshwater clays in, 55.
Mecklenburg-Schwerin, glacial deposits of, 202 ; interglacial deposits of, 279.
Mediterranean, effect of, on migration of plants and animals, 335 ; land-passages across, in Pleistocene Period, 337 ; depths in, 338 ; greater extent of, in late glacial times, 354 ; supposed former communication of, with North Sea, 468 ; mollusca of, in northern seas, 501.
Mellby, arctic flora in peat of, 491.
Menin, borings at, 507.
Mentone, human remains in cave near, 21, 23 ; marmot in caves of, 30 ; glutton in caves of, 113.
Menyanthes trifoliata, 152, 299, 494.
MERCEY, De, on origin of French *limon*, 163, 220.
Mer de glace, slope of surface of, in Scotland, 189 ; Scottish, Irish, and English, coalescent, 190 ; English, coalescent with that of North Sea, 192 ; Scandinavian, effect of, upon chalk of Möen, 200 ; deflections of under strata of, 203. (*See* also Ice-sheet.)
Mersey, submerged forests of the, 431, 432.
Metals, introduction of knowledge of, 378.
MEUGY cited, 153.
Meuse, Palæolithic remains in flood-loam of the, 22 ; löss in valley of the, 146.
Migrations of mammals, in Northern Hemisphere, 35 ; in Pleistocene Period, 36, 347, 352 ; theory of seasonal or annual, 65.
Millendreth Bay, submerged forest in, 431.
Miocene, of Central France, 320 ; plants of, 332 ; implements in, 345 ; man of, 546.
MÖBIUS cited, 284.
Möen, glacial phenomena of, 200 ; succession of changes evinced by glacial and interglacial deposits of, 285 ; submerged peat of, 476.
Mohn Island, freshwater beds in, 470.
MOHN on Norwegian strandlinier, 271.
Mole, 107, 262, 510.
Molignée, caves in valley of the, 100.
Mollusca, in La Celle tufa, 56; in *diluvium gris* near Paris, 59; in calc-tufa of Canstadt, 59 ; in English Pleistocene, 60 ; in löss near Würzburg, 60 ; in Pleistocene of Lyons, 63 ; in löss-beds at Thiede, 148 ; in löss at Steinbach, 152 ; in Belgian löss, 155 ; in interglacial beds of the Birsthal, 302 ; in Leffe interglacial beds, 310 ; in Scottish raised-beaches, 384, 385, 399 ; in Scottish alluvia, 425 ; in English postglacial deposits, 434 ; in Irish raised-beaches, 459 ; in postglacial beds of Sweden and Norway, 466, 467, 469 ; now living round coasts of Norway and Sweden, 467 ; in peat of Champagne, 494 ; southern species of, in northern seas, 501.
Moncalieri-Valenza Hills, marmot formerly lived at foot of, 30.
Mononychus pseudacori, 54.
Montaigle, caves near, 102.
Montchalm, erratics from, 319.
Monte Cinto, ancient glacier of, 213.
Monte Majella, glacial phenomena of, 214.
Monte Mario, shell-beds of, 355.
Monte Rotonda, ancient glacier of, 213.
Mont Dore, ancient glacier of, 211 ; erratics from, 319.
Montpellier maple, 47.
Montpellier, tufas of, 45, 49.
Mont Perrier, glacial and interglacial deposits of, 318.
Montrose, glacial and postglacial deposits of, 403.
Moorwort, 493.
Moraines, contrast between late glacial and postglacial, 412.
Moray Firth, shell-mounds of, 369.
MÖRCH, O. A. L., cited, 501, 502.
Morea, raised-beaches of, 355.
Morecambe Bay, submerged peat of, 431 432.
Moret, tufa near, 46, 50.
Morlaix, submarine forest near, 481.
MORLOT, on interglacial deposits, 252, 297 ; estimate of date of Neolithic Period, 557.
MORO on glacier of Serchio, 214.
MORRIS on large erratics, 194.
Mortillet, De, on classification of French caves, 15 ; cited, 346, 546.
MORTON cited, 191.
Morvan, glaciation of the, 211.
Mosand of Sweden, 472.
Moselle, löss in valley of the, 146.
Mosses, arctic and alpine species of, 55 ; in peat, 492, 494.
Mouligna, river, submerged trees at mouth of, 481.
Mountain avens, 485. (*See Dryas octopetala.*)
Mountain pine, 47.
Mount's Bay, submerged forest of, 431, 440.
Mouse, 367.

Mud in glacial rivers, 232.
Muggendorf Cave, 112.
Mulgedium alpinum, 353.
Murchison on Russian Tchernozem, 158, 163, 242; cited, 203.
Murex lamellosus, 502.
Musk sheep, 17, 24, 25, 29, 32, 39, 40, 134.
Mya, 284; *M. truncata*, 334, 466, 475.
Myodes lemmus, 148; *M. obensis*, 62; *M. torquatus*, 62, 149. (*See* also Marmot.)
Myriophyllum, 485, 492.
Myrtillus uliginosa, 493.
Mytilus edulis, 284, 399, 469.

Nain (N. America), range of temperature at, 39.
Nancy, Pleistocene lignite near, 54.
Nantes, range of temperature at, 39.
Nar-valley beds, 268.
Nassa, 502; *N. reticulata*, 278, 281.
Natica grœnlandica, 467.
Nathorst on arctic flora of Pleistocene deposits, 55; on arctic flora below peat, 54, 485, 491; on plants of Norfolk forest-bed, 262, 335; on Swedish interglacial beds, 270; on postglacial flora of Bovey Tracey, 456; on raised-beaches of Scania, 475.
Naumann detects striated rocks in Saxony, 198.
Neæra cuspidata, 467; *N. rostrata*, 502.
Neanderthal cranium, 21, 23.
Neckar valley, löss of, 145, 151.
Nehring on löss-beds of Thiede and Westeregeln, 147; cited, 245.
Neolithic Age, contrasts between, and Palæolithic, 11, 13, 23, 378; difficulty of ascertaining relative antiquity of relics of, 363; kitchen-middens of, 365; lake-dwellings of, 369; implements of, 372; fauna of, 373; cereals of, 373; passage from, into Bronze Age, 374; people of, 374, 376; rude stone monuments of, 375; long barrows of, 375; caves of, 376; traces of cannibalism in, 377; in Denmark, 487; commencement of, in postglacial period, 534, 535; duration of, 557.
Neolithic and Palæolithic deposits, break between, 446, 449, 481, 496, 547, 553.
Neolithic implements below Järavallen, 473; in Flemish peat, 480; in peat of Somme valley, 480; in Danish peat, 487; in peat of Troyes, 493.
Neolithic man in Scotland, 428.
Neolithic remains, relative position of, in cave-deposits, 75, 119, 120.
Newcastle, range of temperature at, 39.
New Stone Age. (*See* Neolithic Age.)
Nilsson on Järavallen, 473.
Nithsdale, drums of, 183
Nordenskiöld, Prof., cited, 497.
Norfolk, great erratics in, 193.
North America, extremes of temperature in, 34; migrations of mammals in, 36; temperature of east coast of, 39; Glacial Period in, 228.
Northern Asia, extremes of temperature in, 34; migrations of mammals in, 36.
Northern field-vole, 62.
Northern France, löss of, 153.
Northern Germany, interglacial deposits of, 276.
North Sea, path of *mer de glace* in, 192, 203; depths of, 204, 339; dry land during interglacial epochs, 340; dry land in early postglacial times, 509.
Northumberland, glaciation of, 191.
North-west Europe, former geographical changes in, 339.
Norway, glaciation of, 195; carry of erratics in south of, 204; strandlinier of, 271; postglacial shell-beds of, 465, 466; glacial shell-beds of, 466; unfossiliferous postglacial deposits of, 466, 471; peat-bogs of, 487; former wooded condition of, 488.
Norwegian lemming. (*See* Lemming.)
Nova Scotia, southern colonies round coasts of, 502.
Novaia Zemlia, 41, 340.
Nucula tenuis, 467.
Nussdorf, shells in löss of, 237.

Oak, 47, 52, 53, 148, 320, 420, 432, 435, 436, 438, 448, 461, 469, 480, 486, 487, 494.
Obliquity of the ecliptic, 560.
Ochils, 178, 179; flood-gravels from, 387.
Odostomia albella, 467; *O. plicata*, 467.
Oerzenhofs, peat with arctic-alpine plants at, 492.
Olbers on tiers of trees in peat of Sweden, 528.
Oldham cited, 190.
Old Stone Period. (*See* Palæolithic Age.)
Olive, 48, 51.
Olmo, human cranium in Pleistocene of, 22, 318.
Omalius, D', cited, 346.
Onega, height of, above sea, 471.
Ontario, Lake, glacial and interglacial deposits on shores of, 293.
Ophiura Sarsii, 467.
Orkney Islands, 188.
Orne, river, submerged trees at mouth of, 481.
Oronsay, raised-beaches of, 418.
Orth cited, 283.
Osterfjord, strand-lines of, 273, 275.
Ostrea cochlear, 502; *O. edulis*, 399, 468; *O. virginiana*, 503.
Otter, 31, 32, 367, 449, 494.

Outer Hebrides, glaciation of, 178, 189 ; kitchen-middens in, 369.

Ovibos moschatus, 29, 279. (*See* Musk-sheep.)

Owl, 373.

Ox, 40, 107, 108, 138, 148, 150, 151, 367, 373, 456, 463, 480, 494.

Oxycoccus palustris, 493.

PALÆOLITHIC AGE, implements of, 10 ; conditions of life during, 17 ; progress during, 115 ; cold climate in latest stage of, 116 ; conditions of life towards close of, 117 ; alternations of climate during, 117 ; no passage from, into Neolithic Age, 118 ; geographical changes during, 337 ; extent of British area in, 339 ; hiatus between, and Neolithic Age, 378, 446, 449, 481, 547, 553 ; deposits of, their general distribution, 544.

Palæolithic man, implements of, 10 ; artistic work of, 13 ; personal decoration and ornaments of, 14 ; conditions of life of, 17 ; a fisher and hunter, 17 ; acquainted with tailoring, etc., 17; not a cultivator of the ground, 18 ; probably unacquainted with potter's art, 18 ; conjectures as to polity and beliefs of, 19 ; a troglodyte, 19 ; his hearths and refuse-heaps, 19 ; camping-places of, 19 ; visited Mediterranean and Atlantic coasts, 20 ; no proof that he disrespected the dead, 20 ; remains of, in caves, 21, 87, 91, 98, 100, 102, 105, 106, 107, 108, 109, 111 ; not a cannibal, 22 ; types of, 22 ; relative position of remains of, in caves, 75, 119, 120 ; relics of, under löss, 149, 151, 154, 155 ; relics of, under boulder-clay, 263 ; relics of, in Swiss interglacial beds, 300 ; implements of, not found in beds younger than those of last interglacial epoch, 360 ; no trace of, in Scotland, 428 ; no trace of, in postglacial deposits, 443, 449, 496, 547 ; fate of, 546.

PALGRAVE on ancient glaciers of Trebizond and Erzeroum, 214.

PALLAS on débâcles, 173.

Paludella squarrosa, 492.

Paludina balthica, 469 ; *P. diluviana*, 277, 278, 280, 281 ; *P. marginata*, 138.

Panther. (*See* Leopard.)

Paseng, 494.

Patina, 502.

Patrobus excavatus, 54.

PAUL cited, 210.

PAYEN cited, 158.

PEACH, B. N., on glaciation of Caithness, Orkney, and Shetland, 189 ; on Carse of Falkirk, 399 ; on kitchen-middens, 400.

PEACOCK, R. A., on recent extensive submergence in Channel area, 482.

Peat, of Schwerzenbach, 54 ; of Bavaria, 55 ; submarine, of Tay and Earn Valleys, 385 ; of Falkirk Carse-deposits, 399 ; of Scotland, 419 ; submarine, of England, 430 ; of coast of Lancashire, etc., 434 ; of coast of Cornwall, 438 ; of Fenland, 446 ; of inland districts in England, 454 ; submarine, in Ireland, 459 ; with buried trees, in Ireland, 461 ; submarine, on coast of Scania, 473 ; of Danish coasts, 476 ; of Prussian shores of Baltic, 476 ; of Dutch coasts, 477 ; of Friesland, 478 ; of Belgian coast, 479 ; of Somme Valley, 480 ; of Albert and Aveluy, 480 ; of Normandy and Brittany, 481 ; of Arcachon and Biarritz, 481 ; treatises on, 483 ; of Northern Europe, 483 ; varieties of, 485 ; of Denmark, 485 ; of Norway, 487 ; rate of growth of, 489 ; Arctic plants below, 491 ; of Champagne, 493 ; of Central and Southern Europe, 495 ; present decay of, 532.

Pecten grœnlandicus, 387, 403 ; *P. irradians*, 502, 503 ; *P. islandicus*, 385, 466, 467 ; *P. vitreus*, 467.

PENCK, A., on glaciation of Saxony, 199 ; on shells in boulder-clay, 278 ; on succession of glacial deposits in Germany, 281, 286 ; on glacial deposits of Prussia, 281 ; on drift deposits of Saxony, 282 ; on glacial deposits of Denmark, etc., 284 ; on succession of changes evinced by glacial deposits of Möen, 285.

PENGELLY cited, 76 ; on stalagmitic accretion in Kent's Cave, 81 ; on formation of cave-breccia, 85 ; on "stalagmitic ceiling" in Brixham Cave, 87 ; on implements in Kent's Cave, 91 ; on Palæolithic man of Kent's Cave, 93 ; on geographical changes evinced by phenomena of Kent's Cave, 94 ; erratics noticed by, in Devonshire, 227 ; on deposits of Bovey Tracey, 456 ; on mammoth-remains in peat, 457.

Pentewan Work, section of, 440.

Perch, 373.

Perfumed cherry-tree, 50.

Périgord caves, no trace of Palæolithic pottery in, 18.

Periploca græca, 47.

Perran Porth, submerged forest at, 431.

Perrier. (*See* Mont Perrier.)

Perth, buried forest at, 391 ; river-ice in Tay at, 397.

PERTHES, B. de, cited, 3, 4, 123.

Peterborough, postglacial deposits near, 447.
Pettersen, K., cited, 195; on strandlinier, 274.
Pevensey Level, submerged forests of, 431.
Phacidium buxi, 305.
Phillips cited, 158.
Phillyrea angustifolia, 49; *P. media*, 49.
Pholas candida, 468; *P. crispata*, 467.
Phragmites communis, 299.
Physa hypnorum, 302.
Pianico, lacustrine deposits at, 304.
Picea excelsa, 54.
Pidancy cited, 209.
Pierre à Bot, 171.
Piette on beliefs of Palæolithic man, 19; on skulls in Cave of Gourdan, 22, 551, 554; on two glacial epochs in Pyrenees, 323; on Pliocene glaciers, 324.
Pig, 97, 373, 427, 494.
Pigeon, 373.
Pika. (*See* Tailless Hare.)
Pike, 373.
Pilar cited, 209.
Pine, 420, 432, 435, 436, 448, 461, 469, 485, 486, 494.
Pinus abies, 298; *P.* (*Abies*) *alba*, 516; *P. cembra*, 56; *P. larix*, 299; *P. montana*, 54, 299; *P. obovata*, 54; *P. pyrenaiea*, 47, 49; *P. pumilio*, 47, 49; *P. Salzmanni*, 47, 49; *P. sylvestris*, 298, 302, 391, 448, 485.
Pisidium, 449, 492; *P. amnicum*, 280, 299; *P. pulchellum*, 493.
Planchon, G., cited, 45, 48, 49; list of plants in tufa, 49.
Planera, 46.
Planorbis, 449; *P. carinatus*, 149, 302; *P. complanatus*, 310, 475; *P. spirorbis*, 203; *P. vortex*, 302.
Plant, erratics at Leicester, 193.
Plants, rare in Pleistocene deposits, 45; in tufa of La Celle, 50; in travertine of Mamers, 52; in tufa of Canstadt, 53; in lignite of Jarville, 54; in peat of Schwerzenbach, 55; in Bavarian peat, 55, 493; near Montmeilan, 66; of Norfolk forest-bed, 262; of Swiss interglacial deposits, 298; in interglacial beds of the Birsthal, 302; in lacustrine deposits of Val Borlezza, 304; of Leffe lignite, 309; in interglacial deposits of Mont Perrier, 320; migrations of, during last interglacial epoch, 348; migrations of, during last glacial epoch, 352; list of arctic-alpine, 353; in Swedish postglacial beds, 469; in Swedish peat, 492; in peat of Mecklenburg, 492; in peat of Champagne, 494; list of Norwegian, 515; list of, common to Spitzbergen, Germany, etc., 508.
Platanus acceroides, 46.
Pleistocene Period, mammals of, 25; climate of, 33; plants and molluscs of, 44; river deposits of, 121; mammals of, their early arrival, 261; fauna and flora of, same as interglacial, 540; identity of, with Preglacial and Glacial Period, 539; strongly contrasted climates of, 540; date of, 559.
Pliocene Period, reputed glaciers of, 324; flora of, 332; physical and climatic conditions of, 332; first traces of approaching Glacial Period in deposits of, 333; passage from, into Pleistocene Period, 334; incised bones in, 343; worked flints in, 344; man of, 546.
Pleuronectes flesus, 471; *P. platessa*, 471.
Pleurotoma carinatum, 502; *P. turricula*, 385.
Plouescat, submarine forest near, 481.
Poa pratensis, 508.
Poggiarone, cut bones in Pliocene of, 344.
Poland, drifting sands of, 245.
Polecat, 107, 108, 373, 480, 510.
Polgavie, buried forest at, 395.
Poliakoff on glacial phenomena in the Ural Mountains, 210.
Polygonum hydropiper, 299.
Polystichum spinulosum, 494.
Pomatias septemspirale, 57, 59.
Pomel cited, 320.
Pomerania, glacial deposits of, 284.
Pouched marmot, 30. (*See Spermophilus.*)
Populus alba, 49; *P. canescens*, 50, 53; *P. Fraasii*, 53; *P. tremula*, 485. (*See* Aspen.)
Porcupine, 32.
Porlock, submerged forest at, 431.
Porpoise, 367.
Portcounan, raised-beach at, 418.
Porthleven, submarine forest at, 431.
Portlock cited, 190.
Postglacial and recent deposits, of British Islands, 381; of Scotland, 383; of England, 430; of Ireland, 458; of Norway and Sweden, 465; of Finland and Northern Russia, 470; of Denmark 476; of Baltic coast (Germany), 476; of Holland and East Friesland, 477; of West Friesland, 479; of Belgian coast, 479; of French shores of Channel, 479; of Somme valley, 480; of Central and Northern Europe, 482; of Southern Europe, 495.
Postglacial climate of Central Europe, 522.
Potamogeton, 485, 492.
Pottery, reputed Palæolithic, 18; no trace of Palæolithic, in English and French caves, 18; Neolithic, 368, 372, 376; Gallo-Roman, in Flemish peat, 480; in peat of Champagne, 493.

Potsdam, interglacial deposits at, 280.
Pozzuoli, raised-beaches of, 355.
Preglacial and Glacial Period, identity of, with Pleistocene Period, 539.
Preglacial deposits, 261.
Preglacial man, 545.
Prehistoric Period, Later, commencement of, 534.
Preservation of beds under till, 288, 316, 356.
Prestwich cited, 3, 11, 12; on shells in river-drifts, 63; cited, 65; on succession of changes evinced by phenomena of Brixham Cave, 88; on löss at high levels in France, 154; on river-drifts, 124; on geological position of Thames-valley river-drifts, 125; confirms observations of B. de Perthes, 126; on fluviatile origin of river-drifts of Southern England and Northern France, 127; on origin of brick-earth and löss, 130; on flooded condition of Pleistocene rivers, 132; on evidence of river-ice in Pleistocene gravel-beds, 133; on climatic conditions under which river-drifts were deposited, 133; cited, 222, 234; on "head" of Weymouth, 224; on origin of "head," 225; objections to his views, 225.
Privet, 302.
Provence, tufa of, 45, 47.
Prunus mahaleb, 50.
Psammobia ferroënsis, 384.
Pteris aquilina, 49.
Pubescent oak, 47.
Puggaard on glacial phenomena of Möen, 200.
Pumiceous conglomerate of Mont Perrier, 318.
Pumpelly, on dust-storms, 167; on Corsican moraines, 213.
Pupa cinerea, 64; *P. columella*, 152; *P. doliolum*, 57, 152; *P. marginata*, 302; *P. muscorum*, 57, 59, 61, 64, 148, 152, 155, 238; *P. parcedentata*, 61; *P. pygmæa*, 238; *P. quadridens*, 64; *P. secale*, 302.
Purging buckthorn, 494.
Purple boulder-clay, 264.
Purves cited, 256.
Puy de Dôme, glaciation of, 211.
Pyrenees, caves of, 20, 21, 377; ancient glaciers of, 212; two glacial epochs in, 323.
Pyrus acerba, 49; *P. aria*, 47.

Quatrefages, De, on types of Palæolithic man, 22; on Miocene and Pliocene man, 346; on ethnical affinities of Palæolithic races, 552.
Quercus ilex, 47, 49; *Q. mammouthii*, 53; *Q. pedunculata*, 53, 494; *Q. pubescens*, 47; *Q. robur*, 52, 299, 448; *Q. sessiliflora*, 486, 515. (*See* also Oak.)

Rabbit, 31, 32, 87, 113.
Races, Palæolithic, 23, 552.
Raised-beaches, or strandlinier of Norway, 271; of Gibraltar, 326; of Mediterranean, 355; of Scotland, 383, 402, 417, 418, 428, 525; of England, 453; of Ireland, 460; of Sweden, 473; absence of, in north of Scotland, 524.
Ramsay, A. C., on flint implements, 78; on glaciation of Anglesey, 191; on Gibraltar breccias, 216, 324; on two periods of glaciation in Wales, 253.
Rance, De, cited, 191, 432; on postglacial deposits of Lancashire, etc., 434; on sand-dunes of old coast-line in Lancashire, 435; on Neolithic implements in Lancashire, 436.
Raspberry, 48.
Rat, 480.
Reade, T. Mellard, cited, 432.
Red-deer or stag, 31, 32, 40, 87, 91, 103, 107, 108, 113, 138, 151, 262, 367, 373, 426, 438, 449, 463, 480, 496.
Reindeer, 17, 24, 29, 32, 36, 55, 87, 91, 103, 107, 108, 133, 147, 148, 150, 151, 279, 427, 449, 456, 463.
Reindeer migrations, 36, 41.
Reindeer period, 101, 112, 116; stations of, in Central France, 320.
Reindeer, rarity of, in postglacial deposits, 458.
Renevier on frontal moraine of ancient Rhone glacier, 208; cited, 324.
Reusch cited, 195.
Rhamnus catharticus, 494.
Rhine valley, Palæolithic remains in löss of, 22; fauna in Pleistocene of, 63; löss of, 145, 159.
Rhinoceros, 28; *Rhinoceros etruscus*, 28; *R. hemitœchus*, 28, 33, 304; *R. leptorhinus*, 28, 33, 97, 138, 309, 317, 320; *R. megarhinus*, 28, 33, 134, 309; *R. Merckii*, 28, 33, 299; *R. tichorhinus*, 28, 62, 103, 107, 108, 151 (*see* also Siberian Rhinoceros).
Rhodes, raised-beaches of, 355.
Rhone glacier, volume of water and amount of mud discharged from the ancient, 231.
Rhone valley, interglacial deposits in the, 321.
Rhus cotinus, 49.
Rhynconella psittacea, 466.
Ribeiro, C., discovers Pliocene and Miocene implements, 345.
Richthofen, Baron v., dust-storm theory of löss, 165; objections to his theory, 244.
Rink cited, 501.
River-deposits of Pleistocene Period, 121;

first discoveries of flint implements in, 123; Perthes on diluvial origin of, 123; Prestwich's views on, 124; former uncertainty as to relative antiquity of, 125; origin of, 126; high- and low-level, 126; great antiquity of, 127; rate of modern denudation, 128; torrential character of, 130; flood-loams associated with, 131; terraces of, not often preserved, 131; erratics in, 133; Prestwich's views of climatic conditions during accumulation of, 133; evidence of alternate cold and warm climates during accumulation of, 135; mode of determining relative age of, 137; Darwin's views of origin of coarse angular gravels of, 141.

Rivers, of Glacial Period, 233, 234; dammed back by northern ice-sheet, 235; subglacial, in Northern Europe, 239; torrential deposits of, 396; former larger volume of, 398, 407, 455.

Rivière cited, 21.

Rixdorf, interglacial deposits of, 278.

Robertson on unconformity between glacial and postglacial deposits in Scotland, 385.

Roches moutonnées, 176.

Rock-surfaces, glaciated, 176; broken and confused under till, 184, 193, 200.

Rock-terraces, Norwegian, 271; Scottish, 275.

Rodeven, submarine forest at, 481.

Roebuck, 31, 87, 103, 107, 108, 113, 262, 367, 373, 427, 442, 449, 480.

Roemer cited, 150.

Romagnat valley, moraines in, 211.

Romans, destruction of trees by, 530.

Rosa rubiginosa, 515.

Roslyn Hole, great erratic of, 194.

Rose cited, 197.

Roth on German glacial deposits, 277.

Roxburghshire, till of, 183.

Rubia peregrina, 49.

Rubus corylifolius, 515; *R. idæus*, 48, 49, 299; *R. Lindebergii*, 515; *R. radula*, 515; *R. thyrsoideus*, 515; *R. Wahlbergii*, 515.

Rüdersdorf, glaciated rocks at, 197, 201.

Russia, treeless regions of, 35; glaciation of Northern, 196; inundations in Southern, during Glacial Period, 241; postglacial deposits of Northern, 470.

Rütimeyer on relics of man in Swiss interglacial beds, 300; objection to Pliocene age of moraines, etc., near Como, 324; cited, 312.

Sable Campinien, 507.

Sabre-toothed tiger or lion, 26, 33. (*See* also *Machairodus latidens.*)

Saiga, 31, 32.

Sagina Linnæi, 353.

St. Acheul, flint implements from, 11.

St. Andrews Bay, shell-mounds of, 369.

St. Andrews, raised-beaches at, 418.

St. Bertrand-de-Comminges, moraine at, 323.

St. Bride's Bay, submarine forest at, 481.

St. Jacob, interglacial deposits near, 302.

St. Leonards, submarine forest near, 431.

St. Malo, submarine forest at, 481.

St. Michel-en-Lherm, shell-mounds at, 369.

Saint-Pierre-Quilbignon, submarine forest at, 481.

St. Prest, cut bones and flint implements in deposits at, 343.

Salix alba, 49; *S. aurita*, 302; *S. cinerea*, 49, 50, 52, 53, 302, 456; *S. fragilis*, 50, 494; *S. herbacea*, 353, 485, 492, 493; *S. myrtylloides*, 456; *S. polaris*, 55, 262, 335, 485, 492, 497; *S. repens*, 456; *S. reticulata*, 55, 353, 485, 492; *S. retusa*, 497.

Salzmann's pine, 47, 49.

Sambucus ebulus, 50.

Samson, river, caves in valley of, 100, 107.

Sandberger on mollusca in Pleistocene of Würzburg, 60; on mammalian fauna of Franconian löss, 62; on Pleistocene fauna of Rhenish löss, etc., 63; on Steinbach lignite, 152; on shells in löss, 238; on shells in modern flood-deposits of Main, 238.

Sands, drifting, 244.

Sansino, 317.

Santa Luce, cut bones in Pliocene near, 344.

Santa Teresa Cave, 114.

Saporta, Count, on flora of tufas in Provence and Tuscany, 46; list of plants in tufas of Provence, 49; cited, 50, 51, 52, 53; on flora of Canstadt tufa, 53; on present flora of Montmeilan, 66; on Pliocene flora, 332.

Sardinia, breccias of, 65.

Sarsaparilla, 47.

Sars, G. O., cited, 468, 492.

Sars, M., on shells in shell-beds of Norway and present seas, 467, 468.

Savoy, interglacial lignite of, 303.

Saxicava norvegica, 334; *S. rugosa*, 466.

Saxony, glacial phenomena of, 198; broken rocks under till of, 201; drift-deposits, succession of, in, 282.

Scania, kitchen-middens on coasts of, 369; submarine peat of, 473.

Scandinavia, *mer de glace* of, confluent with Scottish ice-sheet, 188; ice-sheet of, invades Eastern England, 192; glacial phenomena of, 194; interglacial beds of, 270; late glacial deposits of, 270; condition of, in late glacial times, 355; postglacial and recent deposits of, 464; condition of, in postglacial times, 500.

Scandinavian flora, 508, 510, 518.

Scharfenort, peat of, 476.

Scheerer cited, 195.

Scheldt, submarine peat near mouth of, 477.

Schimper cited, 212.

Schleswig, submarine peat of, 477.

Schmerling cited, 3, 4, 21.

Schmidt on postglacial beds of Finland and Northern Russia, 470.

Schüssenried, tufa and peat of, 55.

Schwielow-See, boring near, 280.

Schwerzenbach, peat-bog near, 54.

Scirpus lacustris, 299.

Scolopendrium officinale, 49, 50, 52, 53.

Scotland, extent of ice-sheet in, 189 ; slope of surface of ice-sheet in, 189 ; interglacial deposits of, 255 ; submergence of, in last interglacial epoch, 266 ; condition of, during advance and retreat of latest ice-sheet, 267 ; late glacial marine beds of, 270 ; interglacial rock-terraces of, 275 ; buried river-valleys in, 341 ; condition of, in late glacial times, 355 ; shell-mounds of, 369 ; postglacial and recent deposits of, 383 ; raised-beaches of, 383, 418 ; submarine forests and peat of, 385 ; peatbogs of inland districts in, 406, 419 ; former larger size of rivers in, 407 ; traces of postglacial glaciers in, 411 ; ancient forests in, 420 ; postglacial lake-alluvia in, 425 ; postglacial mammalia of, 426 ; relics of Neolithic man in, 428 ; partial submergence of, in postglacial times, 410 ; date of Later Prehistoric periods in, 428 ; former connection of, with Ireland, 512 ; postglacial submergence of, 525.

Scots fir. (*See Pinus sylvestris*, and Pine.)

Scrobicularia piperata, 384, 395, 404, 434, 448.

Seal, 367, 449.

Sections : Brixham Cave deposits, 86 ; Kent's Cave deposits, 90 ; Victoria Cave deposits, 96 ; Trou du Frontal, 109 ; löss-beds of Thiede, 147 ; löss-beds of Westeregeln, 149 ; Steinbach lignite, 152 ; Belgian caves, etc., 156 ; Gibraltar, 217, 326 ; Hailes Quarry, 257, 258 ; Rixdorf sand-beds, 278 ; Wendisch-Wehningen brick-works, 279 ; Schwielow-See, 280 ; lake-deposits of Pianico, 305 ; Leffe lignite, 308, 311 ; Mont Perrier, 320 ; Benghisa Gap, Malta, 328 ; Carse of Gowrie, 386 ; Montrose, 403 ; Scottish postglacial and recent deposits, 408 ; Scottish alluvia, 425 ; Lancashire postglacial, 434 ; Happy Union Works, 438 ; Lower Pentuan Work, 439 ; Pentewan Work, 440 ; Huel Darlington Mine, 440 ; Tramore Bay, 459 ; Norwegian postglacial beds, 466 ; Järavallen, 474 ; Scanian raised-beaches, 475 ; Helsingborg, 475 ; Barsebäck, 475 ; peat-beds near Danzig, 476 ; peat-beds of East Friesland, 477, 478 ; peat of Flemish coast, 480 ; of peat with arctic plants (Sweden), 491.

Seeley on erratic at Roslyn Hole, 194.

Sefström cited, 195, 196, 197.

Seine valley, human remains in Pleistocene of, 22 ; löss of, 153.

Serio, river, fluvio-glacial detritus of, 307.

Serres, Marcel de, cited, 77.

Serval, 25, 32, 113, 325.

Settle, cave near, 96, 119.

Seule, river, submerged trees at mouth of, 481.

Sexe cited, 195.

Sexe, S. A., cited, 195 ; on Norwegian strandlinier, 272, 273.

Sharpness, submerged forest at, 431.

Sheep, 373, 427, 463, 480, 494.

Shell-beds of Norway and Sweden, 465, 467, 474.

Shell-marl, 449.

Shell-mounds. (*See* Kitchen-middens.)

Shells, crushed and striated, in till, 188 ; in flood-deposits of Main, 238 ; transported by sea, 238 ; in German glacial and interglacial deposits, 277, 278, 280, 281, 282 ; in interglacial beds of Holstein and Denmark, 284 ; in Danish kitchen-middens, 367 ; in Scottish raised-beaches, 384, 387 ; in clay at Errol, 386 ; in Scottish postglacial and recent deposits, 399, 425 ; in English postglacial and recent deposits, 439, 449. (*See* also Mollusca.)

Shrew, 87.

Siberian or woolly rhinoceros, 62, 87, 133, 147, 148, 150. (*See* also *Rhinoceros tichorhinus.*)

Siberian pine, 56.

Sicily, caves of, 114.

Sierra Guadarrama, ancient glaciers of, 212.

Sierra-Nevada, ancient glaciers of, 212.

Silene cretica, 373.

Siphonodentalium vitreum, 467.

Sison amomum, 510.

Skegness, submarine forests near, 431, 480.

Skertchly, S. B. J., on erratic at Roslyn Hole, 194 ; on broken strata under till, 194 ; on Brandon interglacial beds with Palæolithic implements, 263 ; on Fenland, 445.

Sleaford, postglacial deposits near, 447.

Smilax aspera, 47.

Smith, Ecroyd, cited, 435, 436.

Smith (of Jordanhill), cited, 174.

Snow, accumulation of, in river-valleys of Pleistocene Period, 141.

Snowy vole, 30, 32.
Södertelge, buried hut at, 474.
Solent, the, formerly a land-valley, 341.
Solway Firth, raised-beaches of, 418; submarine peat of, 431.
Somme (Department), peat of, 480.
„ valley, löss of, 153; peat in, 480.
Sonnaz, interglacial lignite of, 303.
Sordelli on plants in deposits of Val Borlezza, 305; on plants of Leffe lignite, 309.
Sorde, rock-shelter of, 552.
Sound of Jura, raised-beaches of, 418.
Southampton Water, formerly a land-valley, 341.
Southern Europe, caves of, 112; physical conditions of, in postglacial times, 533.
Southern mammals of Pleistocene, 32.
South Wales, glaciation of, 193.
"Sowbacks" of till, 182.
Spermophilus citillus, 30; *S. altaicus*, 62.
Spezia, cave near, 114.
Sphagnum, 493; *S. cymbifolium*, 299.
Spiennes, Palæolithic implements under löss near, 155.
Spindle-tree, 47, 50, 53. (*See* also *Euonymus*).
Spitzbergen, postglacial deposits of, 496; plants of, 508; connection of, with Europe in postglacial times, 521.
Spotted hyæna, 27, 32.
Spruce fir, 54, 494.
Squirrel, 107, 510.
Stache cited, 150.
Stag. (*See* Red-deer.)
Stalagmite, composition and origin of, 79; rate of accretion of, 79, 80, 83; in Kent's Cave, 81, 91, 92; impurities in, 84; sheets of, broken up and removed, 85; in Brixham Cave, 86.
Stanley, Hon. W., mammoth remains in peat at Holyhead, 457.
Stannergate, Dundee, buried land-surface at, 390.
Stanniferous gravels, 438, 442.
Starling, 373.
Steele cited, 531.
Steenstrup cited, 346; on kitchen-middens, 366; on Danish peat, 485; on rate of growth of peat in Denmark, 491.
Stefani cited, 345; on marine deposits of glacial age in Italy, 355.
Steinbach, lignite of, 152.
Steppes, black earth of, 157; inundation of, in Glacial Period, 240.
Stoat, 31, 32.
Stone Age, 6.
Stopanni on moraines of Val d'Arni, 213; on glacial lake of Val Borlezza, 304; of lake deposits at Leffe, 310; on Pliocene glaciers, 324.
Stork, 373.
Stoss-seite, 177.
Straits of Dover, 339, 341.
Strandlinier of Norway, 271.
Strathcluony, successive buried forests in peat of, 421.
Stream-tin gravels, 227.
Striated rock-surfaces, 176.
Striated shells in till, 277.
Striated stones, 180.
Striped hyæna, 27, 32.
Studiati cited, 65.
Sturgeon, 480.
Stuttgardt, tufas near, 53.
Subglacial rivers, etc., 239.
Submarine plateau of 100 fathoms, 339.
Submarine trees and peat of Scotland, 385, 390, 399, 403; of England, 430-453; of Ireland, 458; of Scania, 473-475; of Denmark, Holstein, Hanover, and Prussian coasts of Baltic, 476; of the Elbe, 477; of Holland and East Friesland, 477; of Flanders, 479; of French coasts of Channel, 480.
Submarine trough off southern coast of Sweden and Norway, 515.
Submergence, of British area during last interglacial epoch, 266; in late glacial times, 355; connection between, and humidity of climate, 452; postglacial, of Scandinavia, 465, 472; of Channel area in postglacial and recent period, 481; postglacial, 525.
Succinea, 449; species of, in La Celle tufa, 57; in *diluvium gris* of Paris, 59; in Canstadt tufa, 59; in Würzburg löss, 61; at Thiede, 148; in Steinbach löss, 152; in Belgian löss, 155; in Potsdam interglacial sands, 280; in Swiss interglacial beds, 302.
Sulzer cited, 172.
Sunderland, submarine forest near, 431.
Sus scrofa ferus and *palustris*, 494.
Swan, 373, 494.
Sweden, glaciation of, 195; interglacial beds of, 270; postglacial shell-beds of, 465, 468; unfossiliferous postglacial sands of, 472; submarine peat and raised-beaches of, 473; arctic-alpine plants below peat of, 491; postglacial changes in Southern, 505.
Switzerland, caves of, 112; glaciation of, 207; interglacial deposits of, 297; lake-dwellings of, 369; arctic-alpine flora of, 495.
Sycamore, 50, 51, 53.
Symonds, Rev. W. S., cited, 220.

Tagus valley, implements in Miocene and Pliocene of, 345.
Tailless hare or pika, 30, 32, 42, 113, 147, 149.

Tapes decussatus, 468 ; *T. pullastra*, 468 ; *T. virginea*, 467.
Tapir, 321.
Tarascon, two glacial epochs in valley of, 323.
Taraxacum palustre, 508.
TARDY on deposits of Bois de la Bâtie, 301 ; on deposits in Ain and Rhone valleys, 321 ; cited, 346.
Tatra, extinct glaciers of the, 210.
Tavignano valley, extinct glacier of, 213.
Taxus baccata, 299, 305. (*See* also Yew.)
Tay valley, late glacial marine beds of, 270 ; postglacial deposits of, 386, 388.
Tchernozem. (*See* Black-earth.)
Tellina balthica, 284, 384, 469 ; *T. calcarea*, 266 ; *T. incarnata*, 384 ; *T. myopsis*, 387.
Tempelhof, interglacial deposits of, 280.
Temperate group of Pleistocene mammals, 32.
Temperature, range of, at various places in Europe, 34.
Tenby, submarine forest at, 431.
Terek-thal, extinct glacier of, 214.
Terraces, postglacial fluviatile, 407.
Terre à briques, 154, 164.
TETENS cited, 477.
Teucrium scorodonia, 515.
Thames valley, extension of ice-sheet to, 193 ; Pleistocene deposits of, 125, 137; submerged forest of, 431.
Thessaly, lions formerly infested, 26.
Thickness of extinct glaciers, how ascertained, 177.
Thiede, löss-beds at, 147, 246.
Thoron, glacial and interglacial deposits at, 298.
THOMSON, T., his discovery of arctic shell-beds in Scotland, 174 ; cited, 518.
THOMSON, Sir Wyville, on southern forms in northern seas, 501.
Thuidium antiquum, 299.
Thuja saviana, 46 ; *T. occidentalis*, 46.
THURNAM cited, 377.
TIDDEMAN cited, 97 ; on deposits in Victoria Cave, 98 ; on glaciation of Lancashire, 191.
TIETZE cited, 210.
Tiger, sabre-toothed. (*See Machairodus.*)
Tilia europæa, 48, 49 ; *T. grandifolia*, 53.
Till, 180 ; stones in, 180 ; distribution of, 182 ; parallel ridges or banks of, 183 ; broken rocks under, 184, 193, 200 ; "carry" of stones in, 186, 191 ; colour and texture of, 186 ; aqueous deposits in, 187 ; shells in, 188, 267.
Tinière, cone of the, 557.
Tin-gravels, 438, 442.
Toga, breccia of, 65.
Torbay, mammoth-remains in submarine forest at, 457.
TORELL cited, 196 ; on invasion of Germany by Scandinavian *mer de glace*, 198, 199 ; on buried hut at Södertelge, 474 ; on shell-beds of Spitzbergen, 497.
Torquated lemming, 30, 62.
TÖRNEBOHM cited, 196 ; on postglacial and recent raised-beaches of Scania, 474.
TOURNAL cited, 77.
TOURNOUËR cited, 46 ; on mollusca of La Celle tufa, 56, 135.
Tralee Bay, submarine peat of, 460.
Tramore Bay, submarine peat of, 459.
Trapa natans, 299, 309.
Travertine, of Massa Marittima, 46 ; of Provence, 47 ; of Montpellier, 49 ; of La Celle, 50, 56 ; of Mamers, 52 ; of Canstadt, 53, 59 ; of Southern Europe, 55.
Trebizond, extinct glaciers of, 214.
Treeless zone, 35.
Trees, in Scottish peat, 420 ; large size of, 420 ; often lie all one way, 424, 479 ; marks of fire on, 424, 479 ; of English submarine forests, 432, 433, 438, 439, 440, 448 ; successive tiers of, in peat, 421, 423, 434, 438-440, 448, 451, 461, 485, 487, 488 ; in shell-bank of Enkopings ås, 469 ; in peat of Champagne, 494. (*See* also Forests and Peat.)
TREVELYAN cited, 518.
TRIBOLET on traces of extinct glaciers in Brittany, 227.
Trifolium minus, 515 ; *T. procumbens*, 515.
Tripoli of Val Borlezza, 304.
Triticum turgidum, 373.
Tritonium Sabinii, 466.
Trochus, 502 ; *T. granulatus*, 502.
Trophon clathratus, 399, 467.
Trou de la Naulette, 106.
Trou de l'Érable, 102.
Trou de Philippe, 102.
Trou de Pont-à-Lesse, 104.
Trou du Chêne, 102, 104.
Trou du Frontal, 108.
Trou du Lievre, 102.
Trou du Sureau, 102.
Trou Magrite, 105.
Troyes, peat of, 493.
Tufa. (*See* Travertine.)
TULLBERG, S. A., cited, 492.
Tumuli, skulls in Danish, 368 ; or barrows, 375.
Tundras, 35.
Tunis, raised-beaches of, 355.
Turin, erratics on hills near, 317.
Turritella communis, 434.
Tuscany, tufas of, 45, 46 ; extinct glaciers of, 213.
Tweed valley, till of, 186.
TYLOR, A., cited, 162.

Tyrol, glaciers from, invade low grounds to north, 208.

Ulmus campestris, 49, 52, 53, 105; *U. montana*, 49.
Unconformity between glacial and postglacial deposits, 382, 385, 432, 465.
Unio littoralis, 60, 138.
Upsala, erratics at, 472.
Ural Mountains, glaciation of, 210.
Ursus arctos, 29, 367, 474; *U. arvernensis*, 262, 363; *U. etruscus*, 317; *U. ferox*, 29, 463; *U. spelæus*, 29, 62, 299, 463. (*See* also Cave-bear.)
Urus, 24, 31, 32, 62, 87, 103, 108, 133, 147, 150, 261, 262, 373, 435, 436, 442, 456, 494.
Ussher on post-tertiary deposits of Cornwall, 441, 443, 445.
Utznach, interglacial beds at, 298.

Vaccinium vitis-idæa, 299.
Vaches-Noires, submarine forest near, 481.
Val Adrara, glacial lake of, 315.
Val Borlezza, ancient lake of, 304.
Val Cavallina, extinct glacier of, 304.
Val Concosola, 311.
Val d'Arno, 22, 23, 317.
Valentia, dredging forty miles off, 501.
Val Foresto, glacial lake of, 315.
Val Gandino, lignites of, 306; lacustrine deposits in, 308.
Vallebiaia, traces of marine beds of glacial age in, 355.
Val Camonica, ancient glacier of, 303.
Valley-löss, 146.
Vallières, cave of, 110.
Val Seriana, extinct glacier of, 304.
Valvata, sp., 282, 284; *V. depressa*, 299; *V. obtusa*, 299; *V. piscinalis*, 277, 280, 310.
Vanden Broeck cited, 153.
Varese, peat near, 56.
Venetz cited, 207.
Venus ovata, 284; *V. mercenaria*, 502.
Vergisson Cave, 18.
Veronica alpina, 353; *V. saxatilis*, 353.
Verril on southern colonies in Gulf of St. Lawrence, etc., 502.
Verticordia abyssicola, 502.
Veyrier, cave of, 112.
Vibraye, De, cited, 110, 111.
Viburnum tinus, 47, 49.
Victoria Cave, 96, 119.
Villers, submarine forest at, 481.
Vine, 47, 48.
Virchow cited, 346.
Vitis vinifera. (*See* Vine.)
Vivarais, ancient glaciers of, 211.
Volcanic eruptions in Central France before close of Palæolithic Age, 320.
Voles, 62, 149.
Vosges Mountains, glaciers of, 210; two glacial epochs in, 322.

Waldheimia septigera, 467.
Wales, glacial deposits of, 253; submergence of, 266; beaver in, 456.
Walnut-tree, 46, 48, 53, 309.
Walrus, 170, 449.
Waltershausen on trees in peat of East Friesland, 479; on glaciation of Iceland, 519.
Wapiti, 107.
Ward, J. Clifton, cited, 191.
Warfen, section of peat-beds at, 477.
Wash, The, submarine forests of, 431; postglacial and recent deposits on borders of, 445.
Watchet, submarine forest at, 431.
Water-rat, 87, 107, 367.
Weasel, 31, 32, 107.
Wellington Channel, buried trees on shores of, 516.
Wendisch-Wehningen, interglacial deposits of, 279.
Werra valley, löss of, 146.
Weser valley, löss of, 146.
Westeregeln, löss-beds at, 149, 246.
West Friesland, peat of, 479.
Wexford Harbour, submarine peat of, 460.
Whale, 399, 401, 438, 440, 449, 480.
Whitaker, W., cited, 274.
Whitebeam, 47.
White birch, 302.
White, Buchanan, cited, 391; on immigration of British flora, 507; on distribution of alpine lepidoptera in Britain, 511.
White poplar, 47, 50, 53.
Whortleberry, 302.
Wigtonshire, raised beaches of, 418.
Wild boar, 32, 103, 107, 108, 262, 325, 367, 373, 449, 480, 494.
Wild cat, 31, 32, 107, 367, 373, 427, 456.
Willows, 47, 50, 320, 420, 448, 469, 485, 494. (*See* also *Salix*.)
Wind, absence of violent, in high latitudes during genial postglacial period, 523; erosion by, 244.
Wolf, 31, 32, 91, 103, 107, 108, 151, 262, 325, 367, 373, 427, 449, 456, 463, 480.
Wolfenbüttel, löss-beds near, 147.
Woodsia hyperborea, 353.
Wood, S. V., cited, 193; on succession of boulder-clays in England, 261; on sands and gravels of East Anglia, 263.
Wookey Hole, 94.
Woolly rhinoceros. (*See* Siberian rhinoceros.)
Wolverene. (*See* Glutton.)
Wormit Bay, submarine peat and trees of, 390.
Worsaae cited, 346; on kitchen-middens, 366.

Wurmbrand, Count, cited, 151.
Würtemberg, Pleistocene flora of, 53.
Wych elm, 49.

Yew, 54, 436, 448, 461, 480, 494.
Yoldia arctica, 281, 467, 471 (*see* also *Leda arctica*); *Y. pygmæa*, 403; *Y. pygmæa*, var. *gibbosa*, 466, 467; *Y. pygmæa*, var. *intermedia*, 467.
Youghal Bay, submarine peat of, 460.
Young, J., on glaciers of Loch Skene, 412.
Ystad, submarine peat and raised-beach of, 473.

Zealand, submarine peat of, 476.
Zeuschner cited, 146, 210.
Zipplau, peat of, 476.
Zittel cited, 493.
Zoarcus viviparus, 471.
Zonites aciformis, 56, 59; *Z. Blauneri*, 64; *Z. lathyri*, 64; *Z. obscuratus*, 64.
Zua lubrica, 57.
Zurich, interglacial deposits near, 298.

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